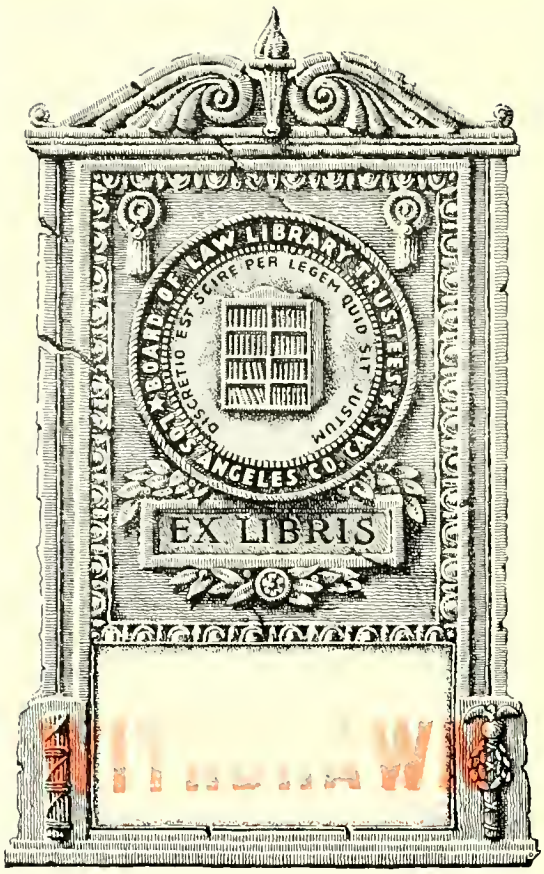

Artist's Conception of Box Canyon Dam and Reservoir
(Mt. Eddy in Background)

State of California

THE RESOURCES AGENCY OF CALIFORNIA

Department of Water Resources

BULLETIN No. 100

MT. SHASTA CITY-DUNSMUIR AREA INVESTIGATION

Preliminary Edition

MARCH 1963

HUGO FISHER
Administrator
The Resources Agency of California

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

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ADDRESS REPLY TO
P. O. Box 388
Sacramento 2, Calif.

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
1120 N STREET, SACRAMENTO

January 21, 1963

Honorable Edmund G. Brown, Governor, and
Members of the Legislature of the
State of California

Gentlemen:

I have the honor to transmit herewith the preliminary edition of Bulletin No. 100, "Mt. Shasta City-Dunsmuir Area Investigation."

The objective of the investigation was to determine the engineering feasibility and economic justification of a water resources development program, which would include a dam and reservoir at the Box Canyon site on the Sacramento River about two miles southwest of Mt. Shasta City.

As a result of the investigation, it was concluded that a dam and reservoir project at the Box Canyon site does possess engineering feasibility, although additional investigation of the damsite foundation is needed for final designs. Either a single-purpose recreation reservoir project or a multipurpose recreation and water conservation reservoir project at Box Canyon would be economically justified. Recreation would be the primary purpose of a multipurpose reservoir. Water conservation would provide a small increment of yield to the State Water Project at the Delta. The single-purpose recreation project was selected as the most desirable project.

The Department of Parks and Recreation has recommended creation of a state park unit at Box Canyon and favors development of a 4,800-acre State Recreation Area at this site in conjunction with the Box Canyon Reservoir Recreation Project.

Department of Water Resources' Bulletin No. 100 recommends that the Legislature authorize the Box Canyon Dam and Reservoir Project as a unit of the State Park System and appropriate funds to provide for advance engineering planning studies.

Sincerely yours,

William E. Warne

Director

Enc.

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

EDMUND G. BROWN, Governor
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ACKNOWLEDGEMENT

Valuable assistance and data were contributed by many agencies and private individuals during the course of this investigation. This cooperation is gratefully acknowledged.

Special mention is made of the cooperation of the following:

United States Forest Service

United States Weather Bureau, Mt. Shasta City

California Division of Beaches and Parks

California Division of Highways, District II

Shasta County Bridge Department

Siskiyou County Road Department

Dunsmuir Public Works Department

Mt. Shasta City Public Works Department

Dunsmuir Water Corporation

Fish and wildlife studies were conducted in cooperation with the following:

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Jack C. Fraser . . . . . Chief, Water Projects Branch

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CHAPTER I. INTRODUCTION

Development of the water resources of the State of California for their best possible use is vital to the continued economic growth of the State. This investigation was initiated in response to the interest displayed by residents of the Mt. Shasta City-Dunsmuir area in the development of their local water resources. Local residents foresee development of the local water resources as another step toward development of a year-round vacation land.

Authorization for Investigation

The investigation was suggested in 1958 by Senator Randolph Collier, Assemblywoman Pauline L. Davis, the Supervisors of Siskiyou County, and residents in the area of Mt. Shasta City and Dunsmuir. The Department of Water Resources conducted a short survey of the potentialities of a reservoir at Box Canyon and in January 1959, published a report entitled "Report on the Desirability of Investigating the Box Canyon Dam and Reservoir Project in Siskiyou County." This report concluded that the investigation was warranted, that it would take two years to complete, and that its cost would be approximately $115,000. In the Budget Acts of 1960 and 1961, the California Legislature authorized the investigation and provided funds of $53,140 and $30,750 to carry on the work during the 1960-61 and 1961-62 fiscal years, respectively.

Objective and Scope of the Investigation

The objective of this investigation was to determine the engineering feasibility and economic justification of a water resources development

program which would include a multipurpose dam and reservoir at the Box Canyon site on the Sacramento River about 2 miles southwest of Mt. Shasta City. The project area is located in Southern Siskiyou County and includes the Sacramento River Basin above the town of Castella. Plate I, "Project Area," depicts this area.

Reconnaissance indicated that a multipurpose dam and reservoir at the Box Canyon site might provide for recreation development, flood control and hydroelectric power generation, might conserve water for agricultural, municipal, and industrial use in the vicinity of the project or in Shasta Valley, and might develop a supplemental water supply to augment downstream water storage.

The actual investigation to determine whether any or all of these purposes would be justified required: (1) studies of water supply, (2) studies of damsite conditions, (3) economic analyses of project purposes, and (4) formulation of a specific project. The scope of such studies, both in the field and in the office, is discussed in the following paragraphs.

(1) Water supply studies to estimate the amount of water available at the Box Canyon damsite included compilation of available precipitation and streamflow records. Temporary stream gages were installed at six locations to provide records of tributary streamflow and to determine minimum summer flows. The completed estimates of water supply were used to determine the size of reservoir needed for the possible uses and benefits for each purpose. Flood hydrology was investigated to determine the spillway requirements for a dam at the Box Canyon site.

(2) Topographic maps of the dam and reservoir site were made by photogrammetric methods as a first step in engineering design. During a geologic survey of the damsite, maps were made to depict the surface and

subsurface formations, and limited auger drilling was undertaken in questionable areas of the damsite. More extensive geologic exploration would be needed before a construction design could be prepared. An investigation was made of locally available construction materials for earthfill, rockfill, and concrete structures.

(3) Design and cost estimates were prepared for several types of dams, including appurtenant features for the various purposes included. These estimates provided a basis for selection of the best location for a dam, economic analysis of the multipurpose features to be included, and formulation of the recommended project.

(4) Engineering and economic studies required to analyze each of the possible purposes prior to formulation of a specific project are discussed in the following sections.

Recreation

Considerable attention was focused on recreation studies to determine present and future recreation needs and uses within the project area. Field investigation included studies of the use of the project area and similar recreation areas by campers and fishermen. Field studies also contributed information which was used in choosing a reservoir size and in delineating recreation areas. A contract was made with the Department of Fish and Game to evaluate the effects of a reservoir at this site on the present stream fishery. Office studies included determination of recreation benefits, development of a recreation land use plan, recommendations of optimum size and operation of a recreation reservoir, and estimates of costs for the required recreation facilities. The benefits of recreation development proved to exceed the cost of such development.

Flood Control

Damage sustained during recent floods in the vicinity of Dunsmuir and Castella was estimated from data collected from local interests and from field interviews with persons who have suffered loss by flood waters. The frequency of damaging floods was estimated and the monetary value of average annual flood damages was calculated. The cost of added facilities required at the damsite for full flood protection was estimated. The cost of providing flood control proved to be greater than the benefits such control would create.

Hydroelectric Power Generation

The amount of power which could be generated at Box Canyon Dam under several operating conditions of various reservoir sizes was estimated. A market analysis of the salability and value of power in this area was completed. Costs of installing power features and producing power to be sold at marketable rates were found to be greater than the estimated benefits. Investigation of power production as a purpose of Box Canyon Dam and Reservoir was discontinued at this point.

Water Conservation

A dam and reservoir at Box Canyon could conserve water for irrigation, municipal, and industrial use both in the project area and in areas supplied by the transfer of water through the State Water Facilities. The following discussion will treat irrigation and municipal and industrial uses separately as they pertain to the project area and jointly as they pertain to supplies transferred through the State Water Facilities.

Irrigation. Two potential water service areas were investigated, (1) local lands along Wagon Creek, and (2) lands of Shasta Valley, near Edgewood, at the uppermost end of the Shasta River Basin.

From a field survey, the amount of irrigable land presently developed in the Wagon Creek area was determined. Data from prior Department of Water Resources studies were used to estimate the total amount of irrigable land in this area and possible future water needs. Field studies, including interviews with local water users, were conducted to determine present water supply. When studies showed that there would be no demand in this area for irrigation water from Box Canyon Reservoir, this phase of the investigation was terminated.

The possibility of exporting water to Shasta Valley for irrigation also was studied. Information collected during prior studies by the Department of Water Resources was used to determine the need of and ability to pay for irrigation water in Shasta Valley. The cost of developing and transporting water from the Upper Sacramento River Basin was found to exceed the expected ability of irrigation water users in Shasta Valley to meet water costs.

Municipal and Industrial Uses. Well drillers, local residents, and representatives of agencies which presently supply water to municipalities and industries in the Mt. Shasta City-Dunsmuir area were interviewed with respect to present and expected future municipal and industrial water supplies. Numerous undeveloped springs near present municipal supplies were inspected during the course of a limited ground water basin study. Estimates of growth in population and in per capita use of water in the project area were made to aid in determining future needs. When studies showed that the foreseeable municipal or industrial demand for water could be met from the development of local springs or wells, no further

consideration was given to the inclusion of urban water supply features in the Box Canyon Project.

Possible Supply to State Water Facilities. When the water supply is low at Shasta Reservoir[1/], releases of water from Box Canyon Reservoir could be transported by the Sacramento River to the Delta where the water eventually would be distributed through proposed state facilities to areas of need. Studies were made to determine the amount of water that would be available from Box Canyon Reservoir for such distribution and the benefits creditable to providing new water at the Delta. These benefits were compared to the costs required to add this purpose to the project and the reduction in recreation benefits. The net benefits would equal the costs of including this water conservation purpose.

Area of Investigation

The Mt. Shasta City-Dunsmuir area is located about 60 miles north of Redding at the headwaters of the Sacramento River. It lies along the bottom of a canyon formed by the Trinity Mountains on the west and Mt. Shasta on the northeast. Although the bordering mountains rise to 9,025 feet at Mt. Eddy and to a spectacular 14,161 feet at Mt. Shasta, the area itself is not at high elevation. The summit of the topographic saddle between Mt. Shasta City and Weed is less than 4,000 feet, and the area funnels into a narrow river canyon at Dunsmuir, where the elevation is about 2,300 feet.

The Box Canyon Reservoir site lies about 2 miles southwest of Mt. Shasta City, just below the junction of the Sacramento River and Wagon Creek. The Sacramento River heads at Gumboot Lake and flows east to this junction. Wagon Creek heads further north on the slopes of Mt. Eddy and flows east just south of the saddle between the Sacramento River drainage

1/ This condition was assumed to occur for about seven consecutive years of the 50-year repayment period of the project.

and the Shasta River drainage basin. It turns south and, as it flows through Wagon Creek Valley to the junction point, picks up the flow of many springs from the slope of Mt. Shasta.

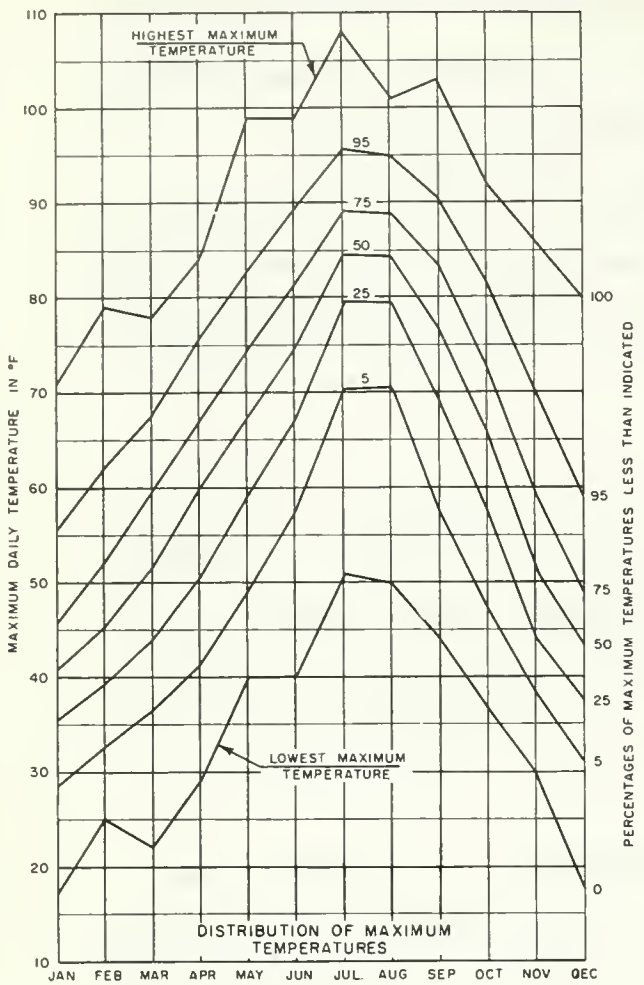
The area is primarily one of pine and fir forests with stands of hardwood forest at the lower elevations. The forest cover, as well as scenic mountains, contributes to the attractiveness of the Mt. Shasta City-Dunsmuir area as a recreation spot.

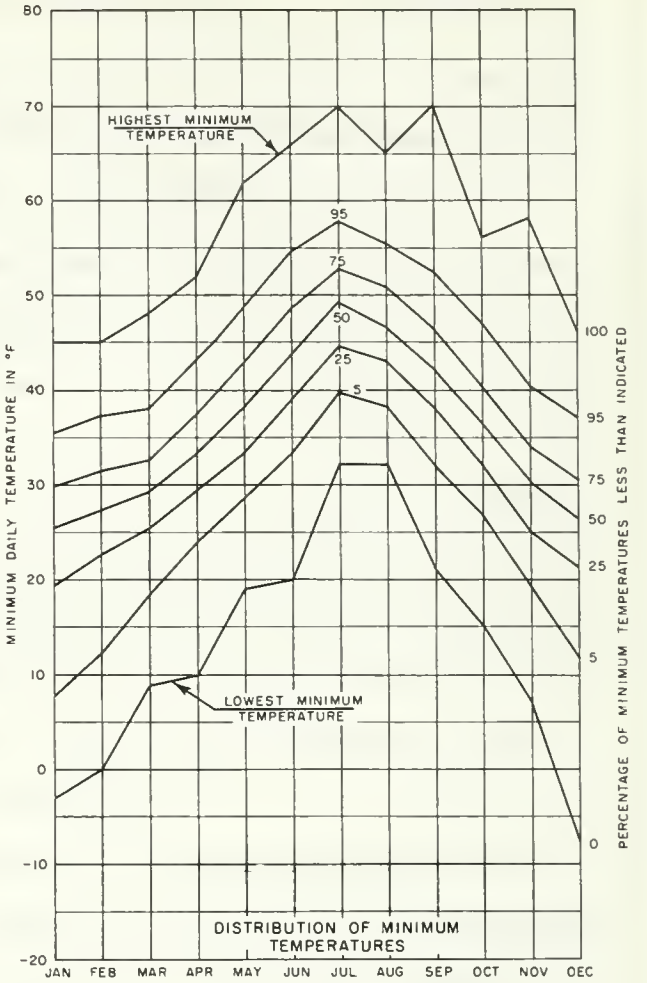
Climate

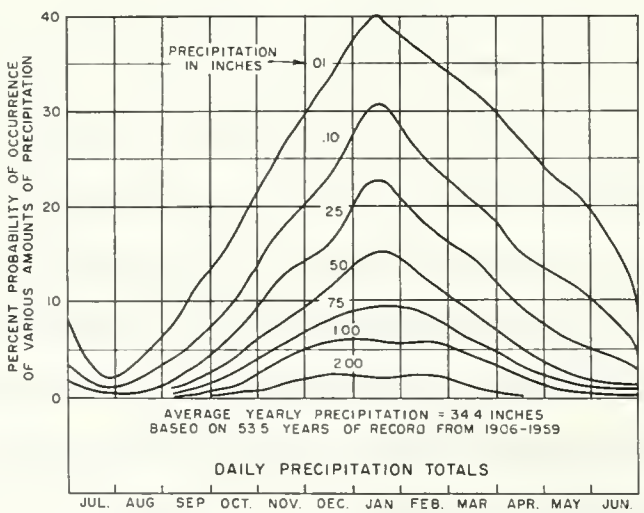
The mild summer climate in the vicinity of Mt. Shasta is a definite advantage to the recreation potential of this area. Summer temperatures reach an average high of 85 degrees Fahrenheit at Mt. Shasta City, and usually rise above 90 degrees only 18 days a year. Night time temperatures are cool.

The winter climate is somewhat more severe. Temperatures drop below freezing an average of 137 days a year with an average low temperature of 24 degrees during the winter months.

Although the summer months are dry, heavy precipitation occurs over the basin during the months from October to June. The average precipitation for the entire drainage basin above Dunsmuir is about 50 inches a year. Average precipitation ranges from about 34 inches at Mt. Shasta City to more than 60 inches at higher elevations. Much of this precipitation occurs as snow which, at higher elevations, remains on the ground until summer. Average annual snowfall at Mt. Shasta City is 102 inches; however, the depth of snow on the ground rarely exceeds two feet. Figure 1 indicates climatic conditions in the project area.







TEMPERATURE AND PRECIPITATION VARIATIONS AT MT. SHASTA CITY

Geology

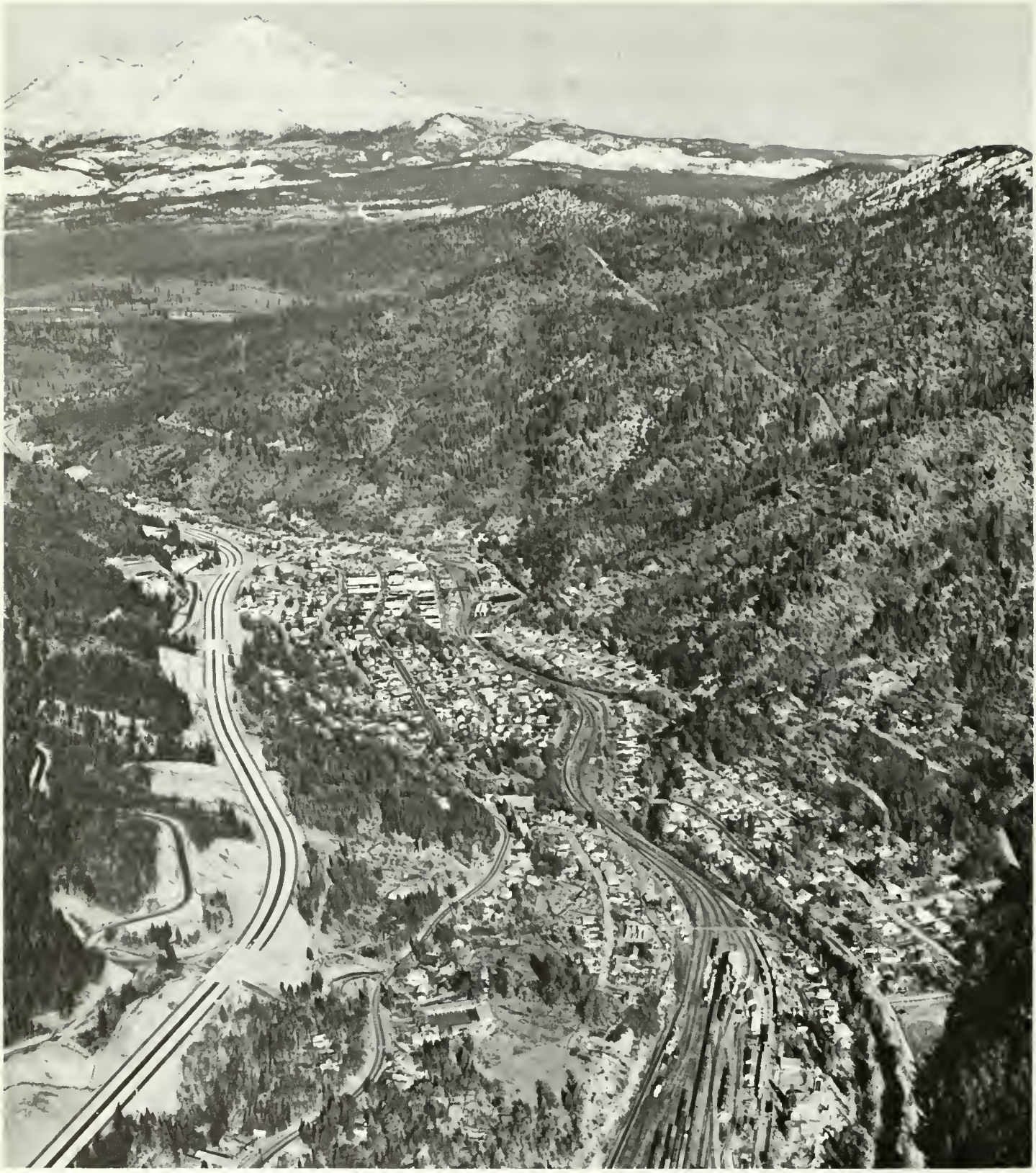
A study of areal geology provided information needed for analysis of the water supply and to appraise the suitability of the Box Canyon Dam and Reservoir site. Volcanic activity has played the major role in the geologic development of this area. Box Canyon damsite is located near the geologic boundary between the Klamath Mountains and the Cascade Range. Characteristic rock formations of both mountain ranges are present nearby.

The Klamath Mountains, lying west of the reservoir area, contain intrusive, sedimentary and volcanic rocks. The Cascade Range contains volcanic rocks which are divided into two units: The Western Cascade series and the High Cascade series. The Western Cascade series, an older outcropping, lies to the west of the peaks of the Cascade Range and extends north from Mt. Shasta into Oregon. The High Cascade series, a younger unit, includes both Mt. Shasta and Mt. Lassen.

The erosion which preceded Western Cascade volcanism created a valley between Rainbow Ridge and Ney Springs Creek. The lava flows that contributed to the Western Cascade series covered any sediments that may have been deposited in this valley. These lava flows outcrop in several places to the west of Box Canyon and in the reservoir area. They form the walls of Box Canyon and apparently terminate a short distance east of the canyon. A lava flow which ages ago blocked the canyon at Mott, several miles below the damsite, formed a lake that extended around the west end of Box Canyon and into the proposed reservoir area. From the proposed reservoir area to Mott, the Sacramento River has exposed the sediments which indicate the past presence of this lake.

Population

Two towns, Mt. Shasta City and Dunsmuir, lie within the area investigated. Illustrations 1 and 2 present aerial views of these towns.



Dunsmuir
(Mt. Shasta in Background)

Mt. Shasta City
(Black Butte in Background)

According to the 1960 census, Mt. Shasta City has a population of 1,963 and Dunsmuir, one of 2,873. Two other towns located quite close to the project area are McCloud, population 2,140, which lies approximately 10 miles east of Mt. Shasta City; and Weed, population 3,223, which lies 8 miles north of Mt. Shasta City. In contrast to the expanding population of many other California cities, the population of each of these four towns has remained nearly constant during the past 20 years.

The 1960 population of the entire project area is about 7,500. It is estimated that the population will grow to about 27,000 within the next 50 years.

Present Development

The Mt. Shasta City-Dunsmuir area lies in a forested area north of the Sacramento Valley. Through this area passes the most favorable transportation route from the Central Valley in California to communities in Oregon and the Northwest. Residents of the Mt. Shasta City-Dunsmuir area have traditionally depended upon lumber, the railroad, and, to a lesser extent, upon agriculture for their livelihood. Although the lumber and railroad industries have experienced a decline in recent years, the income provided by agriculture has remained relatively stable. An additional source of income has resulted from the rapidly expanding use of the area for recreational pursuits.

Lumbering. Prior to settlement of the Mt. Shasta City-Dunsmuir area by the white man, the southern slope of Mt. Shasta and the surrounding territory were covered by virgin growths of pine and fir. Subsequent decades of lumbering and destructive forest fires have reduced the amount of harvestable timber available and left many areas unproductive.

Logging, milling, and transportation of lumber supported the early economy of the area, but the modern practice of hauling logs great distances

by truck and rail has resulted in a reduction of local milling and manufacturing. The dwindling of virgin timber resources and the slow recovery brought by reforestation practices may result in further decline of the local lumber industry. However, the demand for forest products has remained high during recent years and the lumber industry continues to provide a major source of income for the area.

Agriculture. The extent of irrigated and irrigable lands within the Mt. Shasta City-Dunsmuir area is very limited. Agriculture mainly consists of the raising of cattle and those pasture and hay crops required to support cattle. Crops, for profitable production, generally require irrigation from May through October. Most of the acreage suitable for tillage or irrigated pasture is presently developed and provided with irrigation water from the nearby creeks and springs.

Transportation. The location of the Mt. Shasta City-Dunsmuir area on an important interstate transportation route contributes in many ways to the economy of the area.

During the early gold rush days, the main route of travel from the Central Valley to Oregon passed from Redding farther west through the gold-producing areas of Trinity Center and Callahan to Yreka. The route from Redding to Mt. Shasta City was more difficult to open up. Tales are told of the hardships endured by ranchers who drove herds of cattle up the Sacramento River Canyon to reach Shasta Valley. When the railroad was constructed from Redding to Dunsmuir in 1886 and on to Oregon the next year, the first impetus was given to the lumber industry in the Mt. Shasta area.

In addition to its importance to the lumber industry, the Southern Pacific Railroad, with switchyards and track maintenance shops located in Dunsmuir, contributes significantly to the economic life of the project area. Prior to the exclusive use of diesel locomotives on this line, large repair and overhaul shops for steam locomotives were located in Dunsmuir. Because

service for diesel equipment is now provided elsewhere, the railroad reduced its repair shops in Dunsmuir to the minimum. Following this reduction, in the early 1950's, the area felt the impact of the payroll loss. In the ensuing years, economic stability has been achieved and continued employment at the present level is expected.

Highway access has been improved over the years until now, in 1962, most of U. S. Highway 99 between Redding and Mt. Shasta City is built to four-lane standards. This highway branches at Weed with U. S. 99 continuing into Oregon by way of Medford and U. S. 97 by way of Klamath Falls. A connection from Mt. Shasta City to areas farther east in California is provided by State Route 89, which intersects U. S. 299 near Burney.

The north-south highways are heavily used by both automobile travelers and by commercial trucks. The entire system is heavily used by vacationers during the spring, summer, and fall months.

Recreation. The Mt. Shasta City-Dunsmuir area, as well as many other communities in Northern California, is growing in its attraction to recreationists. The reasons for this growth stem both from the natural attributes of the locality and from the population surge in other portions of the State.

The attractiveness of the forests and mountains, coupled with the pleasant climate, provides the setting that recreationists seek. It is true that there are many other such spots in this State, but as the developed areas become crowded, recreationists tend to go to less crowded areas. Modern highways and autos are bringing more and more visitors to the sparsely populated northern areas.

Mt. Shasta itself is an outstanding attraction. The 14,161-foot peak of Mt. Shasta dominates the entire project area. For much of the year snow covers that portion of the peak above 8,000 feet and several glaciers cling year around to the mountain.

Around the skirts of the mountain, and in the McCloud River and Mt. Eddy areas, fish and game abound. The upper reaches of the Sacramento River above Shasta Lake, for instance, are noted for the excellence of their trout fishery. Much of this part of the river lies within the project area. Many small mountain lakes, at elevations of from 5,500 to 7,000 feet, are located in the Eddy Mountains at the headwaters of the Sacramento River. Rainbow, eastern brook, and brown trout inhabit the lakes and streams. To augment the heavily fished areas, the Department of Fish and Game plants many trout from its hatchery at Mt. Shasta City. Each hunting season, hunters fill many bag limits with native deer, bear, squirrel, and quail.

Despite easy access to the project area, however, little has been done until recent years toward the organized development of recreational opportunities in the area, although such opportunities long have been recognized as among the best in Northern California.

In 1958, the completion of the Mt. Shasta Ski Bowl chair lift and lodge initiated a large-scale attempt to popularize the area for winter sports. Heavy snowpacks that reached 200 inches on the slopes of Mt. Shasta long had suggested this possibility. The ski season normally would be long, beginning in late November and continuing through June. Unusually light snowfall plagued the operation of the facilities during the first two seasons, although normal snow conditions prevailed during the 1960-61 season. Nevertheless, during the first year of operation of the ski bowl, retail sales in Mt. Shasta City were reported to have increased considerably. Plans for future development include toboggan, sledding, and cross country ski runs. Private individuals and organizations recently have also developed improved camp grounds along the Sacramento River near Mt. Shasta and at Castle Lake. Such facilities are used during the summer vacation seasons.

Seeking a means to spur their economy further, many residents advocate a reservoir at Box Canyon. Such a reservoir would draw to the area many of the water sports enthusiasts who abound in increasing numbers in California. It would provide additional attractions to fishermen and campers and contribute toward a well-rounded, year-round recreational development which could supplement an economy whose only other major support comes from lumbering, the railroad, and agriculture.

Related Investigations and Reports

The Mt. Shasta City-Dunsmuir Area Investigation included review of several reports of prior investigations by the Department of Water Resources and other agencies. Of major importance are the following:

California Public Outdoor Recreation Plan Committee. "California Public Outdoor Recreation Plan." 1960.

Department of Water Resources. "Water Resources of California." Bulletin No. 1. 1951.

---- "Water Utilization and Requirements of California." Bulletin No. 2. 1954.

---- "The California Water Plan." Bulletin No. 3. 1957.

---- "Northeastern Counties Investigation." Bulletin No. 58. 1960.

---- "Klamath River Basin Investigation." Bulletin No. 83. 1960.

---- "Shasta Valley Investigation." Bulletin No. 87. 1961.

Department of Parks and Recreation. "Mt. Shasta-Siskiyou Area Study, An Analysis of State Park Potentials in Western Siskiyou County." January 1962.

Additional studies relating to water resources and water requirements conducted by such federal agencies as the Bureau of Reclamation, Geological Survey, Soil Conservation Service, and Corps of Engineers were used to the maximum extent possible.

Organization of Report

The following four chapters of this report cover water supply, investigation of a multipurpose project, formulation of a reservoir project, and conclusions and recommendations resulting from the study.

In Chapter II, the water supply available for project use is estimated, taking into consideration impairments to the supply, water rights, and water quality.

The investigation of each separable purpose is discussed in Chapter III, and the justification for including a purpose in the final project is analyzed.

The final project formulated to fulfill the requirements of the economic purposes is described in Chapter IV. Costs and benefits are evaluated, and the engineering feasibility and economic justification are discussed.

Chapter V presents conclusions and recommendations which were reached during the investigation.

CHAPTER II. WATER SUPPLY

The Mt. Shasta City-Dunsmuir area is one of heavy precipitation and abundant water supply. The Sacramento River at the Box Canyon damsite consistently produces a greater runoff from a drainage area of 122 square miles than does the Shasta River, under natural conditions, from a drainage area of 800 square miles at the point where it discharges into the Klamath River.

Precipitation

In the watershed above Box Canyon damsite, the precipitation varies from over 60 inches at high elevations on Mt. Shasta to the east and on Mt. Eddy to the west to less than 40 inches at lower elevations near Mt. Shasta City. On the average about 70 percent of the annual rainfall occurs between December 1 and April 1. Plate 2, "Lines of Equal Mean Annual Precipitation," shows the precipitation pattern on the Sacramento River watershed above Shasta Reservoir.

Surface Runoff

Fall and winter rains on the relatively impervious basin area west of Rainbow Ridge provide one increment of runoff while another increment is provided by the sustained springtime runoff from melting snows in the high mountainous areas. Precipitation on the Mt. Shasta side of the basin does not produce surface runoff directly into the Wagon Creek system, but infiltrates into the extremely porous volcanics to increase ground water storage, and eventually discharges as part of the sustained summer yield. This sustained summer flow is regulated both by storage in the Mt. Shasta snowpack and by ground water basin seepage into the Wagon Creek drainage system. The natural flow of the Sacramento River at Box Canyon damsite during the summer and fall seldom drops below 40 second-feet.

Stream Gaging Stations and Records

Records of discharge of the Sacramento River above Shasta Reservoir are available at four stations. The record of the Trinity River at Lewiston was used to estimate missing years in the Sacramento River records. The stations are listed in Table 1 and locations shown on Plate 2.

Impairments

Nearly all exports and diversions of water from the Sacramento River above Shasta Reservoir occur upstream from Box Canyon damsite. Therefore, all four stream gaging stations on the Sacramento River listed in Table 1 have historical recorded discharges which are less than full natural flow by the amount of impairment upstream from the damsite. The total impairment is composed of three types of use:

- Consumptive use of water on 2,700 acres of irrigated pasture along Wagon Creek
- Export of water from North Fork Sacramento River to Shasta Valley for irrigation
- Domestic use of water in Mt. Shasta City and outlying rural areas

As seen in Table 2, 1960 total impairment was estimated to be 7,900 acre-feet per year. This impairment was assumed to have increased proportionally from 0 in 1890 to 7,900 acre-feet per year in 1955 and to have remained constant through 1960. For the purposes of establishing water supply estimates for project operation studies, upstream use was assumed to be fully developed to 13,200 acre-feet per year by 1970.

Quantity of Runoff

The surface runoff available for storage at Box Canyon Reservoir after 1970 would be the impaired discharge of the Sacramento River at the

TABLE 1

STREAM GAGING STATIONS USED IN ESTIMATING WATER SUPPLY

Station	Operator	Drainage area in square miles	Period of record
Sacramento River			
Near Mt. Shasta	DWR*	129	May 1959 to date
At Castella	USGS**	257	Oct. 1910 - Sept. 1917 Oct. 1919 - Sept. 1923
At Delta	USGS	427	Oct. 1944 to date
At Antler	USGS	461	Oct. 1910 - Dec. 1911 May 1919 - Sept. 1941
Trinity River			
At Lewiston	USGS	727	Oct. 1908 to date

* Department of Water Resources
** United States Geological Survey

TABLE 2

HISTORICAL DEVELOPMENT OF IMPAIRMENTS UPSTREAM FROM BOX CANYON DAMSITE
(In acre-feet)

Years	Wagon Creek diversions	Export to Shasta Valley	Domestic Use	Total
1885-1890	---	---	---	0
1891-1895	---	---	---	700
1896-1900	---	---	---	1,700
1901-1905	---	---	---	2,700
1906-1910	---	---	---	3,600
1911-1915	---	---	---	4,500
1916-1920	---	---	---	5,200
1921-1925	---	---	---	6,100
1926-1930	---	---	---	7,000
1931-1960	5,500	1,600	800	7,900
1961-1970	9,200	1,600	2,400	13,200

damsite after that date. In the preceding discussion it was assumed that at that date the impairments to this discharge would probably reach the maximum. Estimates of future impaired runoff at the site for use in project operation studies, therefore, were made by subtracting the 1970 level of impairments at the site from estimates of natural runoff at the site for the 50-year period 1910-11 through 1959-60. Natural runoff at the site during this period is assumed to be representative of that which would occur during a 50-year period following 1970.

Although no historical record exists for natural runoff at the damsite, such runoff is assumed to be 94.6 percent of the natural runoff occurring at the Mt. Shasta stream gaging station because the drainage area above the site is 94.6 percent of that above the gaging station. Located one and one-half miles downstream from the damsite, the stream gaging station on the Sacramento River near Mt. Shasta provides a continuous record of runoff from May 1959 to October 1960. The natural runoff at the site of the gaging station occurring during the remaining years of the 50-year period (1910-11 through 1959-60) was estimated from the records of the stream gaging station at Castella in proportion to the total volume of precipitation above each station. Because the records at the Castella gaging station themselves did not cover the entire 50-year period, they were extended, primarily by correlation with records at other points on the Sacramento River as well as with the record of the stream gaging station on the Trinity River at Lewiston. All estimates of annual runoff were made on the basis of natural runoff by adding estimated impairments to the recorded flows.

Estimates of annual impaired runoff which would have occurred at Box Canyon damsite over the last 50 years if upstream impairments had been at the 1970 level are presented in Table 3. It was assumed that this 50-year

period may be taken statistically to represent any 50-year period following 1970. The table shows that estimated future average annual impaired runoff during such a 50-year period would be 192,000 acre-feet, with a high of 368,000 acre-feet in the fifth year (1914-15) of the period and a low of 40,600 acre-feet in the 14th year (1923-24) of the period.

Although variations in annual runoff are the basis for water supply estimates, monthly distribution of the year's supply also plays an important role in the ability of a small reservoir to regulate streamflow. For the summers of 1959 and 1960, good records of monthly runoff are available. Monthly runoff estimates were made for the two low flow years of 1923-24 and 1930-31. An estimate was then made of the percentage of years these dry summers would recur. As seen in Table 4, the minimum summer flows expected with 1970 impairments are 500 acre-feet per month or about 8 second-feet, and these minimums would be expected about 4 or 5 percent of the years.

Ground Water

The slopes of Mt. Shasta are covered by deposits of porous volcanic ash and debris blown out during past eruptions or carried downhill by subsequent erosion. Rain falling on the mountain slopes infiltrates immediately; very little runs off in surface streams. Snowfalls are retained on the mountain both as winter snowpack and as permanent glaciers. Melt water runs in torrents down the mountainside for short distances until it, too, infiltrates into the porous soil. Reference to the USGS Weed Quadrangle discloses the near absence of surface drainage from the west and southwest slopes of Mt. Shasta into the Sacramento River. The triangle approximately defined by Dunsmuir, Black Butte, and the peak of Mt. Shasta, about 40 square miles in area, is an area of ground water storage. The numerous springs which emerge from the hillside on the east side of Wagon Creek and the Sacramento River

TABLE 3

ESTIMATED FUTURE* IMPAIRED RUNOFF OF SACRAMENTO RIVER
AT BOX CANYON DAMSITE (1970 IMPAIRMENTS)

(In acre-feet)

Year	Runoff	Percent of average	Year	Runoff	Percent of average
1910-11	250,000	130	1935-36	160,000	83
1911-12	161,000	84	1936-37	207,000	108
1912-13	166,000	86	1937-38	300,000	156
1913-14	367,000	191	1938-39	93,000	48
1914-15	368,000(high)	192	1939-40	255,000	133
1915-16	282,000	147	1940-41	363,000	189
1916-17	132,000	69	1941-42	296,000	154
1917-18	97,000	50	1942-43	162,000	84
1918-19	204,000	106	1943-44	121,000	63
1919-20	104,000	54	1944-45	161,000	84
1920-21	255,000	133	1945-46	164,000	85
1921-22	155,000	81	1946-47	114,000	59
1922-23	121,000	63	1947-48	193,000	100
1923-24	40,600(low)	21	1948-49	167,000	87
1924-25	240,000	125	1949-50	114,000	59
1925-26	155,000	81	1950-51	237,000	123
1926-27	281,000	146	1951-52	252,000	131
1927-28	271,000	141	1952-53	258,000	134
1928-29	97,000	50	1953-54	231,000	120
1929-30	159,000	83	1954-55	134,000	70
1930-31	58,000	30	1955-56	286,000	149
1931-32	100,000	52	1956-57	188,000	98
1932-33	142,000	74	1957-58	357,000	186
1933-34	132,000	69	1958-59	177,000	92
1934-35	173,000	90	1959-60	114,000	59
			Average	192,000	100

*As statistically represented by the period 1910-11 through 1959-60.

TABLE 4

ESTIMATED IMPAIRED MONTHLY RUNOFF OF SACRAMENTO RIVER
AT BOX CANYON DAMSITE FOR SELECTED YEARS (1970 IMPAIRMENTS)

(In acre-feet)

Year	Probability of exceedence, in percent	Month						
		March	April	May	June	July	Aug.	Sept.
1923-24	98	4,850	3,980	1,540	500	500	500	850
1930-31	96	14,300	9,140	4,260	2,210	500	500	1,270
1958-59	46	---	---	18,700	6,310	3,450	1,270	2,570
1959-60	84	23,600	19,400	22,600	10,500	1,750	1,420	2,070

as far south as Dunsmuir are all supplied from this ground water storage, which regulates runoff from the accumulated winter precipitation to a constant rate of flow. The uniform flow of these springs supplies the Sacramento River with a firm base flow at Box Canyon damsite.

Both Mt. Shasta City and Dunsmuir derive their water supply from such uniform springs. There also are many individual household wells in the rural areas outside Mt. Shasta City that draw from the abundant ground water.

Water Quality

Water samples were taken from the Sacramento River above the confluence of Wagon Creek (40N-4W-29L) before and during the field investigation for this bulletin. Mineral analyses were made of these samples to determine the concentrations of mineral constituents in the river water. Table 5 shows how these concentrations compare with the recommended limits for concentrations of specific minerals.

The water proved to be of a type suitable both for irrigating most crops under most conditions and for domestic uses. Although classified as slightly hard, the water generally would require no softening for either domestic or industrial purposes. Determination of the complete suitability of this water for industrial purposes would necessitate tests for heavy metals (iron and manganese), although turbidity, color, odor, and the total amount of dissolved solids are within tolerances required for most water-related industries.

TABLE 5

MINERAL ANALYSIS OF SACRAMENTO RIVER WATER
ABOVE THE CONFLUENCE OF WAGON CREEK
(Average of four samples)

Items	Quality of samples		Recommended limits	
	Range	Average	Irrigation: water class I*	Drinking water**
Constituent (in parts per million)				
Boron	0.03-0.07	0.04	0.5	
Chloride	0.3 -3.3	2.7	175	250
Fluoride	0.0 -0.1	0.0		0.8-1.7***
Hardness	52 -100	75		100
Total dissolved solids	64 -119	91	700	500
Properties				
Sodium in percent of base constituents	4 -8	6	60	
Specific conductance (Micromhos at 25° C.)	99 -195	150	1000	

*Class I irrigation water, as defined by the Department of Water Resources, is suitable for most crops under most conditions.

**U. S. Public Health Drinking Water Standards, 1961, hardness excepted.

***Recommended upper limit varies in accordance with the annual average maximum daily air temperature.

Trout now live and propagate in all tributaries above the reservoir site. Although no standards exist for judging the quality of water required to maintain trout in California mountain streams, studies by the Department of Fish and Game indicate that water stored in Box Canyon Reservoir would support an excellent trout fishery.

Water Rights

Upstream from Box Canyon damsite there are many farms and rural homes which use water from the Sacramento River and its tributaries. These

users are exercising riparian and appropriative water rights. Very few of these diversions are made under licenses or permits issued by the State Water Rights Board.

The exportation of water from North Fork Sacramento River to Shasta Valley is made under a water right license which allows the diversion of 15 cubic feet per second from April 1 to October 10. This export also includes a permit to divert and store 350 acre-feet during the period October 1 to May 15.

An application for 49 acre-feet of storage on Wagon Creek and 49 acre-feet of offstream storage in Metcalf Lake was approved by the State Water Rights Board in November 1961. Water for this storage will be diverted during the winter months. The impairments cited in Table 2 account for the decrease in water supply available for Box Canyon Reservoir as a result of upstream diversions. The storage of surplus waters in the proposed Box Canyon Reservoir would not interfere with upstream water rights.

Between the Box Canyon damsite and Shasta Reservoir there are many riparian owners, but there is very little storage, diversion, or use of Sacramento River water. Applications to permit storage of water in Shasta Reservoir were filed in 1927 by the State of California and were assigned to the Bureau of Reclamation in 1938. Included in the assignment to the Bureau of Reclamation is a clause reserving water to upstream counties of water origin for their future requirements. This reservation would permit the depletion of inflow to Shasta Reservoir by 700,000 acre-feet in any one year, but not to exceed 4,500,000 acre-feet in any ten-year period.

Future reservoirs, such as Allen Camp Reservoir on the Pit River proposed by the Big Valley Irrigation District, and the McCloud River power development plan which the Pacific Gas and Electric Company proposes to build, would increase storage above Shasta Reservoir by only 215,000 acre-feet. Even

if Box Canyon Reservoir, with a capacity of 30,000 acre-feet, were completed in the same year as Allen Camp Dam and the McCloud River Development, the increase in upstream storage would be far less than the allowable depletion to Shasta Reservoir inflow.

CHAPTER III. INVESTIGATION OF SEPARABLE PROJECT PURPOSES

After reconnaisance showed that the possible multipurpose features of a reservoir project at the Box Canyon site would be recreation development, flood control, hydroelectric power generation, and water conservation for agricultural, municipal and industrial purposes, each purpose was studied to determine its necessity, its engineering features, its cost of inclusion in the project, and its potential benefits. The economic justification for inclusion of any purpose in a project requires that benefits derived from the purpose at least equal the cost of including the purpose in the project.

Economic justification studies considered only the costs of adding specific facilities to the project. Preliminary studies showed that a reservoir with a storage capacity of approximately 30,000 acre-feet and a surface area of about 500 acres would be satisfactory for all multipurpose uses. In general, no costs of increasing reservoir storage capacity were included in the estimates of separable costs.

This chapter describes the analysis made of each purpose and the means used to determine whether inclusion of the purpose in the project would be justified.

Recreation

The demand for outdoor recreation facilities increased sharply in California during the years following World War II. This increased demand is attributed mainly to the rapid rise of California population, an increase in leisure time, a higher income per capita, improved transportation, and technological advances in recreation equipment. The California Public Outdoor Recreation Plan, published in 1960, assesses the recreation needs of the people of the State and points out that the demand for outdoor recreation

areas and facilities in California is far greater than the present supply. According to basic recreation data collected for this bulletin, potential users of organized recreation areas in the Box Canyon vicinity presently are turned away and will continue to be turned away in the foreseeable future because the demand for facilities will stay ahead of supply.

The environment of the Box Canyon area is exceedingly suitable to recreation. Surrounding the tentative reservoir would be an area of Southern Siskiyou County noted for its spectacular scenery. The high snow-covered mountains, vast coniferous forests, mountain lakes, streams, and rivers support big game, upland game, and trout fisheries. The public enjoyment of the scenery, and the attractive summer climate at this site would be greatly enhanced when coupled with recreation facilities and the opportunity for good fishing, hunting, and water contact sports.

The "Mt. Shasta-Siskiyou Area Study", completed in January 1962, by the California Department of Parks and Recreation, Division of Beaches and Parks, presents an analysis of the state park potentials in Western Siskiyou County. During the study, it was determined that a Box Canyon Project was one of five projects suitable for inclusion in the California State Park System. The following statement about a Box Canyon Project was extracted from the report:

> "High quality family camping, together with opportunities for enjoyment of the primitive mountain lands to the south and west in the Shasta-Trinity National Forest, are the principal recreational resources, and in themselves will justify the creation of a State [Park] Unit. [However], creation of a 500-acre recreational reservoir by the construction of a dam at Box Canyon would greatly increase the recreational potential of the area and lead to considerably heavier attendance."

It was recommended in the report that the Box Canyon Project be adopted as an official project of the State Park program, and that additional detailed planning and studies be performed pending the availability of funds for its

acquisition and development. The California State Park Commission approved the recommendation and requested that additional studies be included in the 1962-63 planning program.

In the Mt. Shasta City-Dunsmuir Area Investigation, estimates of present recreation use and future recreation demand at Box Canyon were made to determine benefits, required project features, and costs. Estimates of recreation demand "without a project" assume that recreation facility development would continue to take place at the local level. Estimates of recreation demand "with a project" throughout the assumed 50-year economic life of the project are based on the following assumptions:

- Recreation facilities required to supply the demand would be installed.
- The length of recreation season at full use level would be 100 days.
- Box Canyon Reservoir, with a surface area of about 500 acres and appropriate facilities for all uses, would be available.

Estimates of recreation use and recreation demand were made in terms of visitor-days. A visitor-day represents each day or portion of a day that each recreationist spends at the project site in connection with water-associated recreation activities. Recreation benefits were based upon net visitor-days. Net visitor-days are those attributable to the project and are computed by subtracting the number of visitor-days that would occur in the future without a project from the number that would occur with the project. Primary recreation benefits were then computed by multiplying net visitor-days times the appropriate dollar value accruing to the users.

To facilitate predictions of recreation demand, benefits, and subsequent costs of recreation facilities at Box Canyon, recreationists were classified as campers, day-users, and sightseers. The following discussion concerns predictions of recreation demand created by each category and the facilities required to supply that demand.

Campers

Camping parties would stay overnight and utilize project camping facilities. Camp units provided would be of state park standards and generally consist of a fireplace, table, cupboard, parking area, tent space, and water and sanitary facilities shared by several units.

The location of Box Canyon in relation to population centers and the types of recreation activities suitable for development indicate that camping would attract the largest number of recreationists to the area. The family campground would be a hub from which activities such as boating, fishing, swimming, and hiking would originate.

Camping Use Without Project. Mt. Shasta City owns property at the confluence of Wagon Creek and the Sacramento River where campers may use an unimproved area. The city has considered future construction of about 14 camp sites on this unimproved area. At present (1962), in the same vicinity one privately owned campground of approximately eight units is open to the public but has not experienced heavy use. The low use probably reflects lack of public knowledge of its existence. Although other areas along the river are suitable for camp sites, a very small amount of camping takes place annually because no facilities are available. Therefore, for the purpose of this study the amount of camping use in the project area was assumed to remain negligible unless a project offering good facilities were constructed at the Box Canyon site.

Camping Use With Project. The number of potential camper visitor-days at Box Canyon Reservoir was estimated by analyzing historical use data from MacArthur-Burney Falls State Park after examination of other areas providing camp facilities in the region showed that this park was most similar to Box Canyon. In fact, these two camping areas would be almost identical in elevation, temperature, topography, soil type, vegetative types, length of recreation season, proximity to a water body, and distance from large population centers. The MacArthur-Burney Falls State Park lies in Shasta County on State

Highway 299, approximately 60 miles southeast of Mt. Shasta City. Illustration 3 shows the similarity of topography and vegetative types in the two areas.

Because of these similarities, it was assumed that, had the Box Canyon site been developed as proposed, potential camping use in the area during 1960 would have equalled camping demand at MacArthur-Burney Falls State Park during the same year. Estimates of camping demand at Box Canyon for the period from 1960 through 2020 assumed, therefore, that the 1960 camping demand at Box Canyon was 45,000 visitor-days because this was the camping demand which analysis of recreation season records showed existed during 1960 at MacArthur-Burney Falls State Park. Demand projections for years subsequent to 1960 were made by assuming that camping demand will increase in direct proportion to the expected increase in California population and, additionally, will reflect increased per capita participation in outdoor recreation. Such per capita participation in outdoor recreation was estimated from historical trends and is assumed in this report to increase throughout the study period at the rate of 2 percent of the initial use per year.

Recreation use during the first ten years was modified in accordance with an analysis of recreation use data from Millerton State Park which indicates that two-thirds of the use in the tenth year of project operation would occur in the fifth year. It was therefore assumed that during the first decade of operation, Box Canyon Reservoir would experience this same pattern of visitation. Consequently, in addition to the normal increase in use due to population and participation in outdoor recreation, the estimate of use during the first decade of operation was adjusted to correspond to the historical use pattern at Millerton State Park. Figure 2 shows annual projected camping use at Box Canyon between 1970 and 2020.

Camping Facilities. Criteria used to determine the number of camp facilities required to supply the predicted demand at any time during the economic life of the project were as follows:

Beach at Lake Britton, MacArthur-Burney Falls State Park

Box Canyon reservoir area from possible beach site

Beach Sites at Lake Britton and Box Canyon

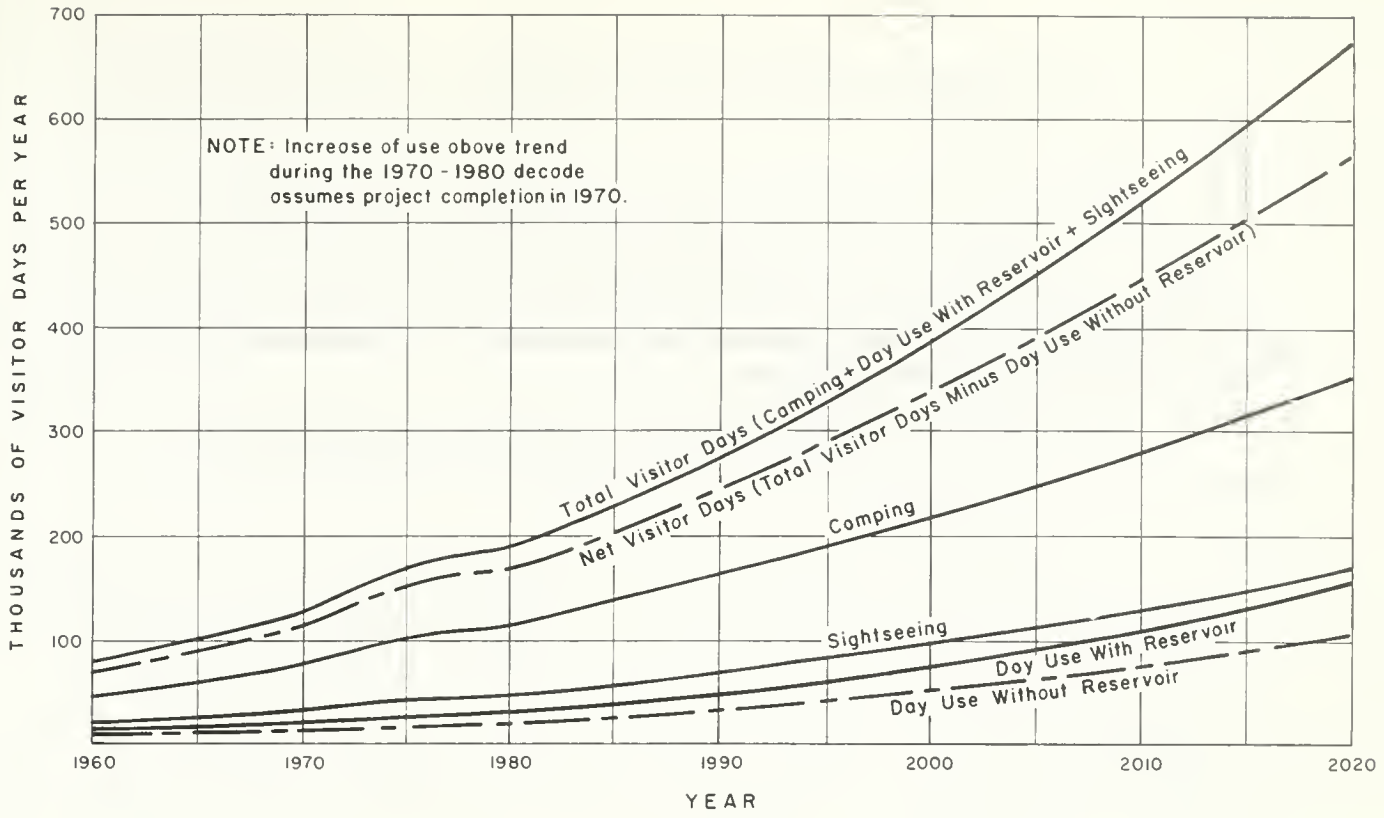


Fig. 2. ESTIMATED RECREATION USE AT BOX CANYON RESERVOIR SITE

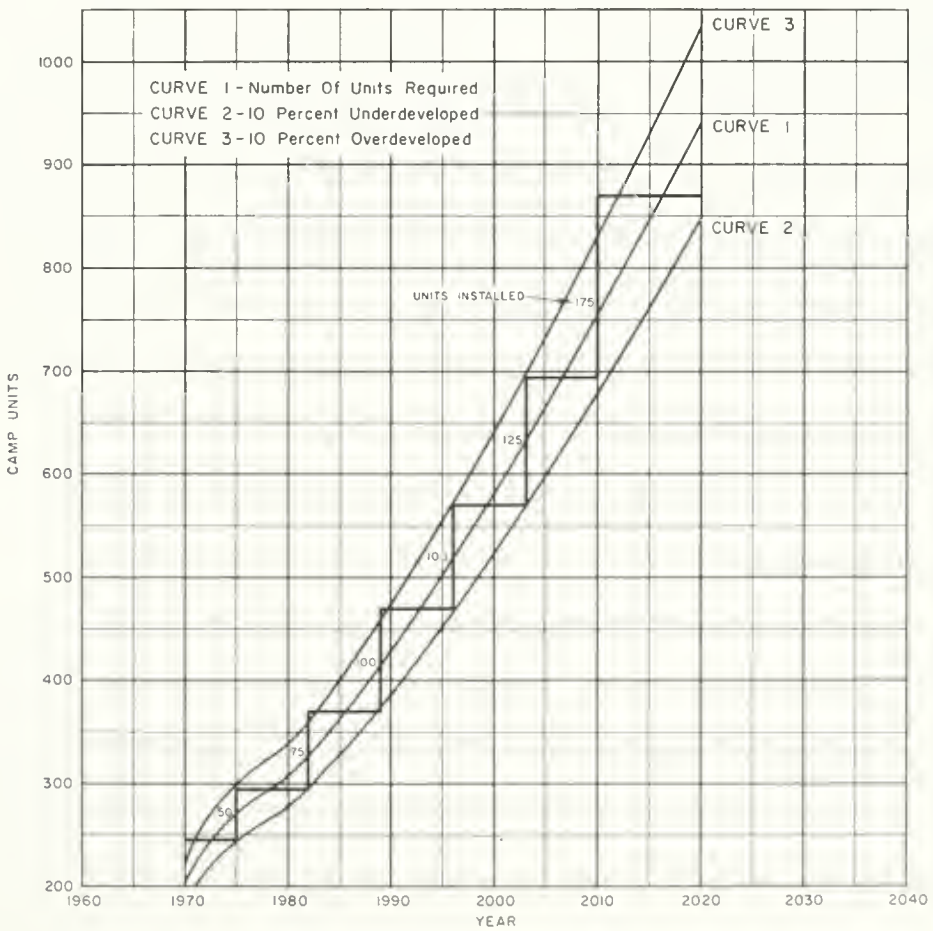


Fig. 3. STAGING OF CAMP UNIT INSTALLATION AT BOX CANYON RESERVOIR

- One camping party uses one camp site for one day and one night.
- The average camping party is composed of 4.2 people.
- Thirty-five percent of the total annual use of camping facilities occurs during the peak month of use.
- Camping facilities should meet the average daily demand during the peak month of use.
- An overload of ten percent during the peak month of use would be allowable before additional facilities would be installed.

Computations using these criteria resulted in the curves presented in Figure 3. Curve 1 shows the number of camping facilities required for predicted demand during the entire study period. Curves 2 and 3 were used to develop limits in staging the installation of camping facilities, and show limits for installing new project facilities whenever the demand exceeds the capacity by ten percent.

Day-Users

Day-users include fishermen, power boat enthusiasts, and beach users. Although day-users do not stay overnight, some are picnickers who use available picnic facilities. The California Public Outdoor Recreation Plan, cited earlier, reports that most day-use parties at recreation areas originate from within a maximum radius of 70 miles and an average of 35 miles from the recreation site, distances indicative of one-day excursions. By these figures, the Counties of Siskiyou, Lassen, Modoc, Shasta, and Tehama lie within the Box Canyon day-use area.

Day-Use Without Project. Present day-use within the project area consists almost entirely of stream fishing. There is very little picnicking and no boating. Youngsters from Mt. Shasta City have fashioned a small "swimmin' hole" near the city's campground site by piling stones into a dam across the Sacramento River. A farm pond in the project area also is used

for swimming. However, total use of both of these swimming areas is relatively small.

During trout season, the State Fish Hatchery at Mt. Shasta City supplements the native trout population which resides in the Box Canyon Reservoir area with weekly plantings of catchable-sized rainbow trout in the Sacramento River and Wagon Creek. These catchables attract the many fishermen who make up the bulk of the nonproject day-users. Surveys conducted during 1960 and 1961 by the Department of Water Resources and the Department of Fish and Game resulted in the estimate that present annual day-use (including swimmers) in the project area amounted to 9,000 visitor-days.

Using this estimate as a beginning point, future day-use without a reservoir was estimated for the period from 1960 through 2020. Projections assumed that use would increase in direct proportion to the expected increase in population of the Counties of Siskiyou, Lassen, Modoc, Shasta, and Tehama, and utilized the annual rate of increase in per capita participation in outdoor recreation which was developed for camping use projections. Figure 2 shows the projected day-use without a project.

Day-Use With Project. Recreation facilities and a reservoir with a stable water surface at Box Canyon would provide many opportunities for day-use activities which do not presently exist in the area and would enhance further those activities presently enjoyed. Good swimming, beaches, boating areas, a launching ramp, picnic facilities, and an excellent reservoir fishery would become available under project conditions.

Following analysis of both population distribution and the results of a recreation survey conducted at Dwinnell Reservoir in Shasta Valley in 1958, potential day-use for 1960 under project conditions at Box Canyon was estimated at 13,000 visitor-days. The reasonableness of this estimate was

checked by comparing it to the visitor-days of use experienced by several newly developed reservoirs.

The area within 15 miles of the project includes the Cities of Mt. Shasta, Dunsmuir, McCloud, and Weed, and has a total population of about 14,000 people. An annual day-use rate of one visit per capita from this combined population would result in 14,000 visitor-days of day-use at Box Canyon. The estimate of 13,000 visitor-days for 1960, if a reservoir had been available at Box Canyon, appears conservative.

The 1960 estimate day-use of the Box Canyon area with a project was used as a starting point to estimate day-use to the year 2020. Such estimates used the same method of increasing day-use in proportion to the population increase of Siskiyou and neighboring counties, and in proportion to the increase in per capita participation in outdoor recreation. Figure 2 shows day-use, visitor-day projections with a reservoir.

Day-Use Facilities. Comparison of the tentative Box Canyon Reservoir with similar reservoirs and interpretation of the 1958 recreation use survey at Dwinnell Reservoir resulted in the following estimated percentages of day-users who would participate in various activities at Box Canyon:

- Fishing: 40 percent
- Boating and water skiing: 20 percent
- Swimming: 20 percent
- Picnicking: 20 percent

Fishing was assumed to be the most attractive day-use activity because of the high potential of Box Canyon as a trout fishery. Boating and water skiing may not be as popular here as elsewhere because of the limited size of the proposed reservoir, as compared to the large surface areas of other reservoirs in this section of the State. Adequate zoning of the reservoir should be provided to prevent conflicts in use.

Picnic units to be provided generally would consist of a fireplace, table, and parking area. Water and sanitary facilities would be shared by several units. All units would meet state park standards. Criteria used to determine the number of picnic units required to supply the predicted demand at any time during the economic life of the project were as follows:

- One and three-fourths day-use parties use one picnic unit daily during the peak month of use.
- The average day-use party is composed of 4.2 people.
- Picnic units should provide for all picnickers, one-quarter of the boaters, and incidental use by fishermen and swimmers.
- Picnic units should meet the average daily demand during the peak month of use.
- An overload of 10 percent during the peak month of use would be allowable before additional facilities would be installed.

Computations using these criteria resulted in the curves presented in Figure 4. Curve 1 shows the number of picnic facilities required for predicted demand during the entire study period. Curves 2 and 3 were used to develop limits in staging the installation of picnic facilities.

In addition to picnic facilities, a boat launching ramp, beach areas, sanitary facilities, bathhouses, and parking areas would be provided for day-users.

Sightseers

Individuals in this category would be in the area only a short time and would make use of overlook vistas, parking areas, and sanitary facilities installed at project expense. They would also utilize any concession facilities available.

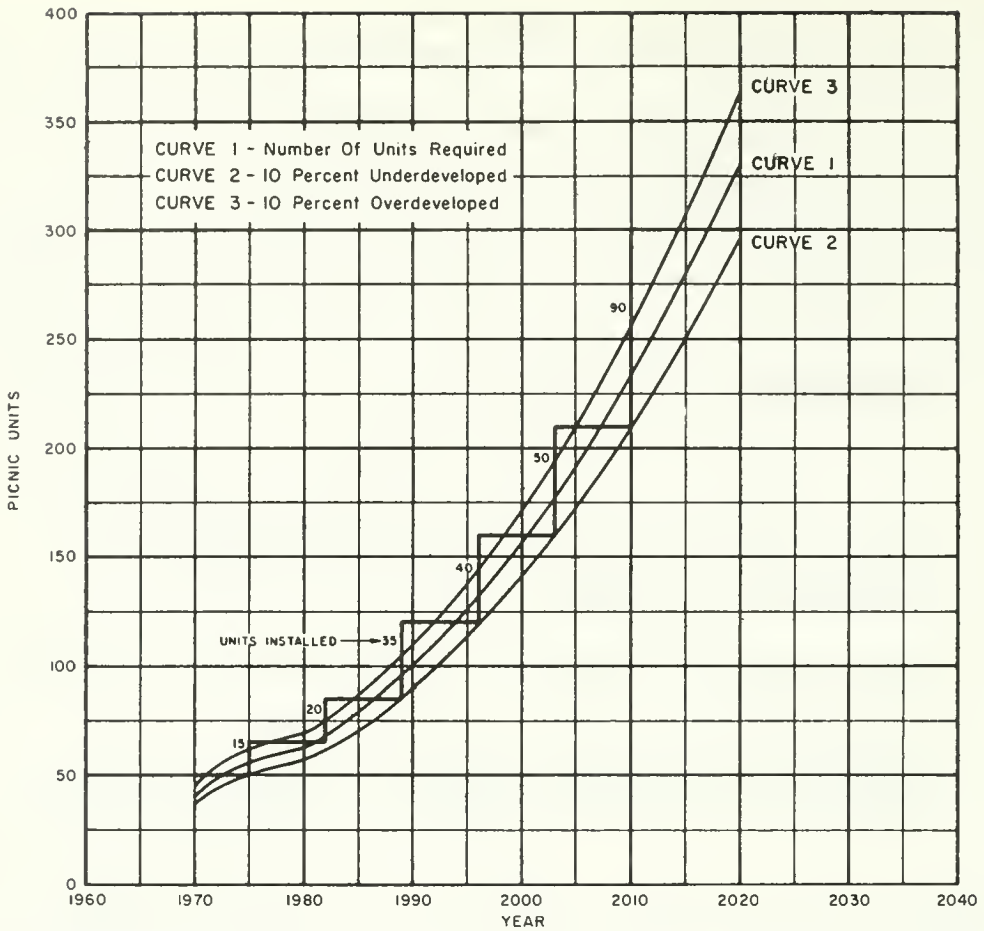


Fig. 4. STAGING OF PICNIC UNIT INSTALLATION AT BOX CANYON RESERVOIR

Demand for Sightseeing. An average of 27 percent of the recreation visitors to 18 projects reported in the 1958 summation of U. S. Bureau of Reclamation recreation data were sightseers. At Friant, Folsom, Sly Park, Stony Gorge, and Cachuma Reservoirs in 1959, an average of 28 percent of the recreation visitors were sightseers, according to additional data supplied by the bureau. The Mt. Shasta-Skiskiyou Area Study, published in January 1962 by the California Division of Beaches and Parks, states that sightseers represent approximately 50 percent of the recreationists in District I, which includes the Counties of Shasta, Siskiyou, Trinity, Modoc, Lassen, Del Norte, Humboldt, and Tehama, as well as part of Mendocino County.

Sightseer use of Box Canyon, however, probably will most nearly approximate the U. S. Bureau of Reclamation averages at reservoir projects because Box Canyon will more nearly represent this type of recreation area than those with outstanding natural attractions such as MacArthur-Burney Falls or Castle Crags State Parks in Shasta County. Therefore, it was estimated that in addition to the campers and day-users, sightseers numbering 25 percent of the total recreation use would also visit Box Canyon Reservoir. These are considered to be net sightseers since present sightseeing use is negligible.

Facilities for Sightseers. A desirable location for a vista overlooking the Box Canyon Reservoir is shown on Plate 3, "Recreation Land Use Plan." Cost estimates for recreation facilities include the development of this vista as well as that of a parking area and sanitary facilities.

Summary of Recreation Use

Table 6 summarizes estimates of recreation use with and without a project in terms of visitor-days of use by the three defined categories of recreationists: campers, day-users, and sightseers.

Recreation Benefits

As has been stated, recreation benefits of a project are determined by multiplying the number of net visitor-days attributable to the project times the dollar value of a visitor-day. The dollar value of a visitor-day to campers and day-users at Box Canyon Reservoir would be $2.30. That to sightseers would be 50 cents, in accordance with the minimum value, believed to be conservative, set by the Department of Water Resources for recreation benefits.

The "Consumer's Surplus" method, described in Appendix A, Bulletin No. 59-2, "Investigation of Upper Feather River Basin Development," was used to obtain the dollar value of a visitor-day to campers and day-users.

As applied to recreation, a consumer's surplus occurs when some people pay more than others for the same recreational pleasure. To compute the size of this difference or surplus, travel costs are assigned to expected visitor origins. The difference between the median travel cost and that cost below which 90 percent of the visitor-day expenses occur, constitutes the consumer's surplus or visitor-day value.

Estimates of travel cost per visitor-day utilized data gathered during field investigation at MacArthur-Burney Falls and Castle Crags State Parks. Such data included the number of people in each party, the area of origin of each party, and the number of days each party spent in the area. A figure of $7\frac{1}{2}$ cents per mile was used as the average travel expenditure.

Project recreation benefits were computed first as the totals accruing during each decade of a 50-year repayment period using the projected net visitor-day values previously discussed and the value of $2.30 per visitor-day for campers and day-users and that of 50 cents per visitor-day for sightseers. The total benefits for each decade were then reduced to present worth values at the beginning of the project to express benefits in the same financial terms as total costs. A summary of this procedure presented in Table 7 shows that the present worth value of total recreation benefits at the proposed Box Canyon Reservoir would be $9,470,000.

Recreation Costs

As previously stated, a reservoir with 30,000 acre-feet of storage capacity and a surface area of about 500 acres was considered to be satisfactory for all proposed project purposes. Therefore, the estimate of separable recreation costs was based on the cost of adding camping and picnicking facilities, a boat launching ramp, access roads, and sightseeing facilities.

TABLE 6

ESTIMATED RECREATION USE OF THE PROPOSED BOX CANYON PROJECT

(In Visitor-Days Annually)

Year	With Project					Without Project		
	Campers	Day-Users	Total Campers and Day-Users	Sightseers	Total Visitor days	Day-Users*	Net Campers and Day-Users	Net visitor days
1960	45,000	13,000	58,000	19,000	77,000	9,000	49,000	68,000
1970	75,000	19,000	94,000	31,000	125,000	13,000	81,000	112,000
1980	113,000	29,000	142,000	47,000	189,000	20,000	122,000	169,000
1990	161,000	47,000	208,000	69,000	277,000	33,000	175,000	244,000
2000	217,000	74,000	291,000	97,000	388,000	51,000	240,000	337,000
2010	281,000	109,000	390,000	130,000	520,000	75,000	315,000	445,000
2020	351,000	154,000	505,000	168,000	673,000	106,000	399,000	567,000

*Figures are given for day-users only because without a project the number of campers was assumed to be negligible.

The number of sightseers without a project was assumed to be zero.

TABLE 7

RECREATION BENEFITS FROM BOX CANYON RESERVOIR

Decade	Campers and day-users during decade			Sightseers during decade			Present worth of total recreation benefits, in dollars
	Net visitor-days	Benefits, in dollars		Net visitor-days	Benefits, in dollars		
		At $2.30 per visitor-day	Present worth		At $.50 per visitor-day	Present worth	
1971-1980	1,060,000	2,440,000	2,000,000	400,000	200,000	160,000	2,160,000
1981-1990	1,485,000	3,420,000	1,900,000	580,000	290,000	160,000	2,060,000
1991-2000	2,075,000	4,770,000	1,790,000	830,000	420,000	160,000	1,950,000
2001-2010	2,775,000	6,380,000	1,620,000	1,140,000	570,000	140,000	1,760,000
2011-2020	3,570,000	8,210,000	1,410,000	1,490,000	750,000	130,000	1,540,000
Totals			8,720,000			750,000	9,470,000

Estimates of the cost of camping and picnic facilities were made using average cost figures supplied by the Division of Beaches and Parks. The value of $3,000 per unit for camp and picnic sites includes the costs of developing the site, of installing tables, fireplaces, and cupboards, and of sanitary facilities, water supply, and access roads within areas containing 50 camp and picnic sites. Additional costs were added to provide for development of water supply sources, main access roads, beach improvement, and boat launching ramps.

Annual operation, maintenance, and replacement costs were computed on the basis of 40 cents per visitor-day for all recreationists. Total costs of installation, operation, maintenance, and replacement are presented in Table 8.

The 1970 present worth values of cost of recreation facilities, operation, maintenance, and replacement are presented in Table 9. The present worth value of total recreation facilities costs would be $4,107,000.

Economic Justification

When reduced to a comparable basis of present worth values in 1970, benefits and the separable cost of the recreation purpose of the Box Canyon Project have been estimated at $9,470,000 and $4,107,000, respectively. Because recreation benefits exceed separable recreation costs, recreation may be included as a purpose in the Box Canyon Project.

Consideration of possible alternatives in or near the Mt. Shasta City-Dunsmuir Area did not reveal another water development project that would fulfill the recreation demand estimated for this area to the extent described for the Box Canyon Project.

Flood Control

Economic justification of including flood protection works as a purpose in the proposed Box Canyon Reservoir was investigated by comparing the costs of

TABLE 8

STAGING OF BOX CANYON RECREATION FACILITIES

Year	Recreation units: Camp* Installed	Camp* Total	Picnic** Installed	Picnic** Total	Total
1970	245	245	50	50	295
1975	50	295	15	65	360
1982	75	370	20	85	455
1989	100	470	35	120	590
1996	100	570	40	160	730
2003	125	695	50	210	905
2010	175	870	90	300	1,170
2020	-	870	-	300	1,170

*From Figure 3, curve 2
**From Figure 4, curve 2

TABLE 9

COSTS OF BOX CANYON RECREATION FACILITIES

Year of repayment period	Time interval in years	Costs of recreation facilities, in dollars: Capital costs Total	Capital costs Present worth	Operation, maintenance, and replacement costs*** Annual	Operation, maintenance, and replacement costs*** Total, time interval	Operation, maintenance, and replacement costs*** Present worth	Total present worth
0		968,000	968,000	50,000			968,000
	5				250,000	227,000	227,000
5		201,000	165,000	67,000			165,000
	7				470,000	337,000	337,000
12		294,000	184,000	82,000			184,000
	7				570,000	310,000	310,000
19		417,000	198,000	107,000			198,000
	7				750,000	310,000	310,000
26		433,000	156,000	137,000			156,000
	7				960,000	302,000	302,000
33		541,000	148,000	168,000			148,000
	7				1,180,000	282,000	282,000
40		819,000	171,000	204,000			171,000
	10				2,040,000	349,000	349,000
50							
Total			1,990,000			2,117,000	4,107,000

***Annual costs computed at $.40 per visitor-day for all recreationists

providing protection to the benefits of flood damages prevented. The benefits must be greater than the cost of providing protection to permit justification of the protective works.

Areas of Historical Damage

Past flooding of the Sacramento River has caused serious damage downstream from the Box Canyon damsite in the areas shown on Plate 1. Canyon walls along the reach of the river between the damsite and Shasta Lake are steep and only small amounts of flat flood plain occur at intervals along the river. Various measures for flood protection have been attempted in some of the developed areas in the flood plain, but much of the area remains subject to repeated flooding.

The City of Dunsmuir has experienced flood damage to streets and sewer lines, and the levee around the sewage treatment plant has suffered severe damage twice in recent years. Private residences and business establishments also have been damaged by flood waters.

Floods also have damaged Castella, located at the confluence of Castle Creek and the Sacramento River. Most of the damage here has been to business establishments and private residences.

The main line of the Southern Pacific Railroad follows the course of the Sacramento River through the canyon from Shasta Lake to the Cantara Loop about 2 miles below Box Canyon damsite. During periods of severe flooding, bridge damage and track washouts have occurred at several places along this portion of the line.

Flooding of the Sacramento River has damaged roads and bridges in the Dunsmuir-Castella areas of Siskiyou and Shasta Counties.

Present Flood Protection Works

Most of the existing flood protection works along the Sacramento River in the Dunsmuir-Castella area have been provided by local residents and agencies. However, the federal government supplied funds for some channel improvement and repair of damaged levees following the floods of 1955 and 1958.

Many private residences in Dunsmuir and Castella are built right on the banks of the river. In order to protect their homes and properties from flood waters, many property owners have built retaining walls to restrain the river. The Southern Pacific Railroad has constructed a large concrete wall along the west bank of the river in Dunsmuir to protect its rail yard. Following the flood of 1940, in which flood waters overtopped the east bank and damaged several homes and businesses in Dunsmuir, the city constructed a concrete retaining wall which contained both the 1955 and 1958 floods. However, during the 1955 flood the water is reported to have risen to the top of the wall.

A levee around the seepage ponds at the Dunsmuir sewage treatment plant was reconstructed following damage during the 1958 flood and appears to be sufficient to restrain a flood similar to the one which occurred in 1940. Illustration 4 pictures this levee. Other smaller levees have been constructed in Dunsmuir in an attempt to avert future damage.

Following the 1955 flood, funds obtained from the federal government were used for channel cleaning and improvement along the Sacramento River just downstream from the U. S. Highway 99 bridge at Dunsmuir. These improvements have increased carrying capacity of the channel and lessened the possibility of flooding in that area.

Benefits From Flood Control

The benefit from flood protection is expressed in terms of the estimated average annual flood damage which would be prevented by the project.

Levee at Dunsmuir Sewage Treatment Plant (1960)

Estimated Historical Damages. A survey of historical flood damages in the areas delineated on Plate 1 was made to aid in determination of the annual flood damage. Three major floods have occurred in the last 20 years for which some damage estimates were available. The greatest flood of record, during the past 50 years, occurred in February 1940, and was followed by floods in December 1955 and February 1958. Several reliable estimates of damage are available for the floods of 1955 and 1958, but information concerning the 1940 flood damages is difficult to obtain.

Table 10 presents a summary of estimated damages to residential areas, commercial establishments, agriculture, industry, utilities, and public facilities in the Dunsmuir-Castella area during the floods of 1940, 1955, and 1958.

Estimated Future Damage. Future flood occurrence was based on a statistical analysis of the frequency of past flooding during the period of record (1910-1960). Table 11 shows the probability of exceedance, or the percent of time, that annual flood peaks are expected to exceed various flood magnitudes ranging from 400 to 15,000 second-feet. Table 11 also shows the estimated monetary damages, as obtained from a flood damage curve, for floods of various magnitudes. The flood damage curve was constructed following analysis of the probabilities of exceedance of floods of various magnitudes, and estimates of past and future flood damage. Predictions indicated future flood damage would result whenever flows in the channel past Dunsmuir exceeded 5,000 second-feet and overtopped existing local flood protection structures.

If full protection from all floods up to those with intervals of 100 years is assumed, average annual flood damage during a 100-year period would be $5,500. This relatively low damage may be attributed mainly to three factors:

- Total damages experienced in recent floods in the flood plain are comparatively small.

TABLE 10

ESTIMATED HISTORICAL SACRAMENTO RIVER FLOOD DAMAGE
TO DUNSMUIR-CASTELLA AREA

Date	Flow at Dunsmuir, in second-feet	Flood damages, in dollars
March 1940	11,800	55,000
December 1955	9,600	46,000
February 1958	8,500	33,700

TABLE 11

ESTIMATED SACRAMENTO RIVER FLOOD DAMAGE
TO DUNSMUIR-CASTELLA AREA AT SELECTED ANNUAL PEAK FLOWS

Annual peak flow at Dunsmuir, in second-feet	Probability of exceedance, in percent	Estimated annual flood damages, in dollars
400	100	---
4,000	34	---
5,000	23	---
6,000	15	7,000
7,000	11	15,000
8,000	7	26,000
9,000	5	41,000
10,000	3.6	48,000
11,000	2.7	52,000
12,000	1.8	55,000
13,000	1.4	57,000
14,000	1.0	105,000
15,000	0.75	110,000

- o The occurrence of damaging flood flows is relatively infrequent.
- o Locally constructed flood protection works prevent damage that in the past occurred from small, frequent floods.

Flood Control Benefits. Flood control benefits attributable to a project are defined as the amount of flood damages prevented by the project. Therefore, if all damages from floods with recurrence interval up to 100 years are prevented in the Dunsmuir-Castella area, the average annual benefit attributable to the project would be $5,500.

Cost of Flood Control

The cost of a reservoir used for flood control is dependent upon the cost of providing sufficient storage capacity for flood control and release facilities beyond the normal facilities required in a reservoir not used for flood control.

Flood Control Requirements. Control of floods with a reservoir is accomplished by reserving during the flood season a portion of the reservoir storage capacity to store flood water. Following the flood threat, flood water stored can be released in a steady nondamaging flow.

Analysis determined the flood control features and operations that would have to be incorporated in the proposed Box Canyon Reservoir to meet the flood control requirements. The probabilities of exceedance of floods at the damsite and at Dunsmuir were estimated by correlation with the probabilities of exceedance measured at other stream gaging stations on the Sacramento River. Table 12 presents magnitudes of flows estimated for various probabilities of exceedance at Delta, Dunsmuir, and at Box Canyon damsite.

The nondamaging channel capacity at Dunsmuir is estimated to be 5,000 second-feet. The drainage area of Box Canyon damsite is 122 square miles, and the drainage area of the Sacramento River above Dunsmuir is 161 square miles. Table 12 shows that the peak flow at Dunsmuir is about 50 percent

TABLE 12

ESTIMATED ANNUAL FLOOD PEAKS FOR SACRAMENTO RIVER
ABOVE DELTA GAGING STATION

Probability of exceedance, in percent	Annual peak flow, in second-feet		
	Box Canyon damsite	Dunsmuir	Delta gaging station
50	2,000	3,100	13,000
20	3,500	5,300	23,000
10	4,700	7,100	31,000
5	6,000	9,000	38,000
2	7,800	11,800	50,000
1	9,300	14,000	60,000

TABLE 13

FLOOD CONTROL ACCOMPLISHMENT
OF 15,000 ACRE-FOOT FLOOD CONTROL
RESERVATION AT BOX CANYON RESERVOIR

Probability of exceedance, in percent	Peak inflow to reservoir, in second-feet	Maximum discharge from reservoir, in second-feet	Annual peak flow at Dunsmuir, in second-feet	
			Uncontrolled	With project
4	6,200	2,000	9,300	4,700
2	7,800	3,000	11,800	5,000
1	9,300	4,000	14,000	5,000
0.1	15,000	15,000	23,000	23,000

greater than the peak flow at Box Canyon damsite. Because of this, Box Canyon Reservoir could control the flow at Dunsmuir only partially. In the case of a flood with a recurrence interval greater than 1-in-100 years, the inflow between the dam and Dunsmuir may be 5,000 second-feet -- equal to the channel capacity at Dunsmuir.

Trial flood control operations determined the reservoir storage capacity required for control of floods of various magnitudes. The following operating criteria were used:

- During the flood season (about October 1 through April 1) a given flood control reservation would be maintained by releasing all inflow.
- As flows increased during a flood, the release at Box Canyon Reservoir would be increased until the discharge at Dunsmuir reached 5,000 second-feet and thereafter manipulated to limit the discharge at Dunsmuir to this amount; excess flood waters would be stored in the reservoir.
- During recession periods following a flood, stored flood waters would be released to regain the flood control reservation as rapidly as possible without exceeding the channel capacity at Dunsmuir (5,000 second-feet).

With a 10,000 acre-foot flood control reservation, a flood at Dunsmuir of 11,800 second-feet (1-in-50-year flood) could be reduced, under this method of operation, to the required 5,000 second-feet. However, a flood at Dunsmuir of 14,000 second-feet (1-in-100-year flood) could be reduced only to 10,000 second-feet, 5,000 second-feet in excess of the channel capacity at that point. A flood control reservation of 15,000 acre-feet would be required to reduce such a flood to the required 5,000 second-feet and the rate of release from the reservoir would have to be 4,000 second-feet. Partial control could be accomplished with a smaller flood control reservation and a smaller release rate. Table 13 demonstrates the flood control accomplishment at Dunsmuir with a 15,000 acre-foot flood control reservation in Box Canyon Reservoir.

Cost of Flood Control Facilities. This analysis assumed that a multipurpose Box Canyon Project would be constructed to a capacity of 30,000 acre-feet and that a 15,000 acre-foot flood control reservation would be maintained from October 1 through April 1. Operation of Box Canyon Reservoir for flood control purposes would require that the outlet works be enlarged to 4,000 second-feet from the 300 second-foot capacity required for maintenance of the downstream fishery and emergency drawdown of the reservoir for the safety of the structure. The cost of the larger outlet works in excess of the smaller represents the cost of adding flood control to the list of project purposes. No cost was assigned to the reservoir storage capacity necessary to maintain the flood control reservation. Assigned costs are shown in the following tabulation:

- Estimated cost of outlet works for flood control: $500,000
- Estimated cost of outlet works for stream maintenance: $200,000
- Estimated added cost of flood control facilities: $300,000

The equivalent average annual cost of a capital investment of $300,000 is $14,000, assuming an amortization period of 50-years and annual interest at four percent.

Economic Justification

The average annual benefit derived from providing a measure of flood control to the Dunsmuir-Castella area by storage and regulated release of flood flows at Box Canyon Reservoir was estimated at $5,500. The average annual cost of facilities required to prevent flood damage was estimated at $14,000. Because costs of added flood control features exceed benefits, flood control as a purpose in the Box Canyon project is not economically justified and should not be included in final project formulation.

Hydroelectric Power

The possibility of generating hydroelectric power by release of water stored in a reservoir at Box Canyon was considered by the California-Oregon Power Company (now Pacific Power and Light Company) in the 1950's. Similar plans investigated by the Department of Water Resources are discussed in Bulletin No. 3 "The California Water Plan, 1957." Both of these investigations were based on a project whose primary purpose would have been power generation. Both plans would have exported water from a reservoir at Box Canyon to be used for power generation in a series of powerplants in the McCloud River system.

In the Mt. Shasta City-Dunsmuir Area Investigation, the possible inclusion of hydroelectric power generation as a purpose in a multipurpose project at the Box Canyon site was studied. Results of this study are presented in the following sections.

The Power Market

Until its merger in 1961 with Pacific Power and Light Company, the California-Oregon Power Company supplied electrical power to the Mt. Shasta City-Dunsmuir area. Pacific Power and Light Company presently supplies this service. During the present investigation, however, no information as to the power loads and resources of the Pacific Power and Light Company was available. Power market studies, therefore, utilized data pertaining to the California-Oregon Power Company. These studies showed that, by 1968, the California-Oregon Power Company would need power in addition to that provided by its available hydroelectric resources. The most likely source of such additional power would be through purchases from the Pacific Gas and Electric Company. Because the value of potential energy from Box Canyon Reservoir is based on the cost of energy from the most likely alternative source, it was assumed that power from the reservoir could be sold at the rate that the Pacific

Gas and Electric Company charged the California Power Company for electrical energy in 1960. The 1960 contract rate is as follows: dependable capacity component, $19.80 per dependable kilowatt per year; and energy component, 3.35 mills per kilowatt-hour.

Box Canyon Hydroelectric Power Potential

Studies were conducted to attain the maximum economic development and utilization of the power resources at Box Canyon damsite. The powerplant was located at streambed elevation (2,900 feet) at the lower end of Box Canyon to take advantage of the additional 100 feet of head made available by the difference in elevation between this point and the damsite. A power canal and penstocks would convey water from the reservoir to the powerplant. The hydroelectric power production studies involved the coordinating and combining of the proposed Box Canyon powerplant into a fully coordinated and integrated power system in the northern part of California and southern part of Oregon. The period of study covered a hydrographic cycle from 1910 through 1960.

The average annual energy production based on the historic runoff (1910-1960) was estimated to be 20,000,000 kilowatt-hours. The critical adverse water period for power production begins in July 1923, and continues through February 1925. The potential energy available during the critical period was estimated to be 15,000,000 kilowatt-hours per year.

The capacity factor of hydroelectric power in an adverse water year determines the dependable capacity of the plant. Substantially all of the system hydroelectric capacity is operated in the peak of the load, and practically all of the hydroenergy of each plant is required to make the plant capacity dependable in supplying that segment of the load to which it is assigned. Based on dry year hydrologic conditions and an annual capacity factor of 42.5 percent, the dependable capacity of the proposed Box Canyon powerplant was estimated to be 4,000 kilowatts.

The power production estimates are based on a reservoir and facilities with the following characteristics:

Maximum reservoir storage:	35,000 acre-feet
Minimum reservoir storage:	5,400 acre-feet
Average net head:	290 feet
Overall efficiency of powerplant:	80 percent

Applying the power values as indicated in the preceding section to the estimated power accomplishments of 4,000 kilowatts of dependable capacity and 20,000,000 kilowatt-hours, the power benefit would be $146,200 annually.

Cost of Power Facilities

A power development at Box Canyon damsite would require the following major facilities:

- Powerplant (4,000 kilowatts) located at the lower end of Box Canyon and approximately 5,000 feet downstream from the dam.
- Pipeline (approximately 5,000 feet long) leading from an outlet in the dam to the penstock of the powerplant.
- Surge tank
- Penstock (approximately 600 feet long)
- Small dam located downstream from the powerplant and constructed to form an afterbay for regulation of downstream releases.

The capital cost of the powerplant was estimated to be $816,000. Other features, including pipeline, surge tank, penstock, and afterbay dam, would cost about $720,000. Total capital cost of power facilities would therefore be about $1,536,000. Total annual costs of $190,000 would include $94,000 for capital recovery with interest at 4 percent, replacement, insurance, and general expense; $68,000 for operation and maintenance; and $28,000 for taxes foregone.

Economic Justification

The foregoing analyses show that the estimated average annual power benefit is $146,200 per year while the estimated average annual cost of producing power is $190,000. Costs therefore exceed benefits and the purpose is not economically justified. Unevaluated factors which would further increase costs and reduce benefits are: (1) the allocation of any costs of reservoir storage capacity for hydroelectric power generation, and (2) annual reservoir drawdown, which would deter recreation use and reduce recreation benefits.

The generation of power at Box Canyon Reservoir is not economically justified under present economic conditions, therefore, and should not be included as a purpose in formulation of the Box Canyon Project.

Irrigation

Two potential irrigation water service areas which might utilize water that could be conserved by the Box Canyon Project were located and studied. These two areas are: (1) the local lands along Wagon Creek, and (2) the southernmost portion of Shasta Valley near Edgewood. These areas are shown on Plate 1. Studies were made of the present and future irrigation demands that would occur in these service areas and of the water supplies available to meet such demands. Where demands were shown to exist, engineering and economic studies were made to determine whether the inclusion of water conservation for irrigation supplies in the Box Canyon Project would be economically justified.

Wagon Creek Valley

Studies of irrigation water supplies in Wagon Creek Valley were restricted primarily to an analysis of present and future demand for water.

Water Requirements. Almost all of the presently irrigated land in Wagon Creek Valley is devoted to pasture such as that pictured in Illustration 5. Small amounts of alfalfa, some small orchards and vegetable gardens make up the remainder of the irrigated lands.

In the Department of Water Resources' Bulletin No. 58, "Northeastern Counties Investigation," the extent of land presently irrigated in Wagon Creek Valley was estimated to be 2,770 acres. Consumptive use of water by vegetation of the type in Wagon Creek Valley is about 2 acre-feet per year. Therefore, the present total consumptive use for the area is about 5,500 acre-feet per year. Because the service area is upstream from the proposed reservoir, consumptive use of water was assumed to represent the water requirement.

Irrigated Pasture in Wagon Creek Valley

Approximately 1,440 additional acres in Wagon Creek Valley are classified as potentially irrigable, as shown on Plate 1. Most of this land lies around the perimeter of land presently under irrigation. More shallow soil depths and rolling to hilly topography make this undeveloped land less desirable for irrigation, but in general it would be satisfactory for pasture and hay crops. It was assumed that this land would be cleared of trees and brush and brought under irrigation during the life of the project. Assuming the same consumptive use of water for this acreage as for presently irrigated acreage, the irrigation water requirement for this area would be about 3,000 acre-feet per year. The total maximum consumptive irrigation requirements of both present and future irrigable lands in Wagon Creek Valley were estimated to be about 8,500 acre-feet per year.

Water Supply. The present supply of irrigation water for lands along Wagon Creek is diverted directly from the stream by holders of riparian and appropriative water rights. Only in dry years is there presently a deficiency of irrigation water in Wagon Creek Valley, and then only at a few diversion points upstream from the confluence of Wagon and Spring Creeks.

Field inspection during this investigation and information obtained from well owners and drillers in the Wagon Creek area indicate that ground water may be pumped from depths of 20 to 40 feet. This ground water basin appears to be relatively constant and should furnish enough water to meet adequately that portion of the estimated maximum irrigation demand over and above that met by Wagon Creek.

The Box Canyon Reservoir site is located downstream from the irrigable lands in Wagon Creek Valley. The maximum water surface elevation in the proposed reservoir would be from 100 to 400 feet lower in elevation than the irrigable lands. The cost of water pumped from the reservoir would be greatly in excess of the cost of pumping from the underlying ground water basin.

Therefore, additional requirements for irrigation water in Wagon Creek Valley probably would be supplied by further development of Wagon Creek waters and by pumping from the ground water basin. Because no demand is anticipated for water from a reservoir at Box Canyon to irrigate Wagon Creek Valley, this purpose was not included in the formulation of the Box Canyon Project.

Export to Shasta Valley

The Shasta River watershed is separated from the Sacramento River watershed by a ridge which connects Mt. Eddy and Mt. Shasta. Shasta Valley contains extensive areas of irrigable land for which no water supply is available. Production on many areas presently irrigated is curtailed because of inadequate local water supplies. Importation of water from other sources is needed for maximum development in Shasta Valley. One Shasta Valley rancher presently is exporting water northward from the North Fork of the Sacramento River for use on irrigated pasture lands in the Shasta River watershed.

The possibility of developing additional water for export from the Sacramento River watershed to Shasta Valley was studied in the Mt. Shasta City-Dunsmuir Area Investigation. Two plans were considered under the assumption that all water available from this source could be beneficially used in Shasta Valley.

Water Requirements. The present agricultural economy of Shasta Valley is based upon livestock and the growth of feed for livestock, but small acreages of field and truck crops, including seed crops, have been planted. Water required for irrigation of these crops currently is supplied by several water service agencies from the Shasta and Little Shasta Rivers. With the exception of occasional dry years, the present supply of irrigation water in Shasta Valley is considered equal to the present requirements. The proximity

of the Shasta Valley area to the Sacramento River watershed and the possibility of developing a gravity flow transfer system similar to the existing Yreka Ditch makes the southern Shasta Valley area the logical service area for water exported from the Sacramento River. In the Department of Water Resources' Bulletin No. 83, "Klamath River Basin Investigation", maximum water requirements of the valley were estimated to be 381,000 acre-feet per year. The bulletin stated that even with maximum development of local water supplies in Shasta Valley, about 270,000 acre-feet would have to be imported from areas such as the Klamath and Sacramento Rivers to supply the ultimate needs. Lands lying at the southern end of Shasta Valley in the Eddy, Parks, and Willow Creeks area shown on Plate 1 would have an estimated maximum supplemental requirement of approximately 138,000 acre-feet per year, according to the bulletin.

Water Supply. The two methods for supplying irrigation water to Shasta Valley from the Upper Sacramento River watershed are: (1) the Tributary Diversion Plan to divert water from the streams tributary to the Sacramento River above Box Canyon damsite and to convey this water around the ridge into Shasta Valley, and (2) the Box Canyon Reservoir Diversion Plan to pump water directly from a reservoir at Box Canyon into a similar conveyance system to flow by gravity into Shasta Valley.

Appraisal of estimated streamflow records of the Sacramento River near Mt. Shasta (1910-1960) shows that the average flow for the months of February through May exceeds 20,000 acre-feet per month. This four-month period was chosen as the period during which unregulated flow could be diverted from the South, Middle, and North Forks of the Sacramento River and from Deer Creek to be stored in a reservoir at Deetz on Wagon Creek.

The following major works would comprise the Tributary Diversion Plan:

- Diversion structures on four of the tributaries listed in Table 14, would allow diversion of excess winter streamflows, but would not interfere with normal summer flows.

- The conveyance system of concrete-lined canals and flumes, ranging in capacity from 75 to 175 second-feet, would convey water from the initial diversion point at elevation 3,900 feet on the South Fork Sacramento River to an offstream storage reservoir at a point about 19 miles northward. Water would be collected enroute from the other three diversion structures.

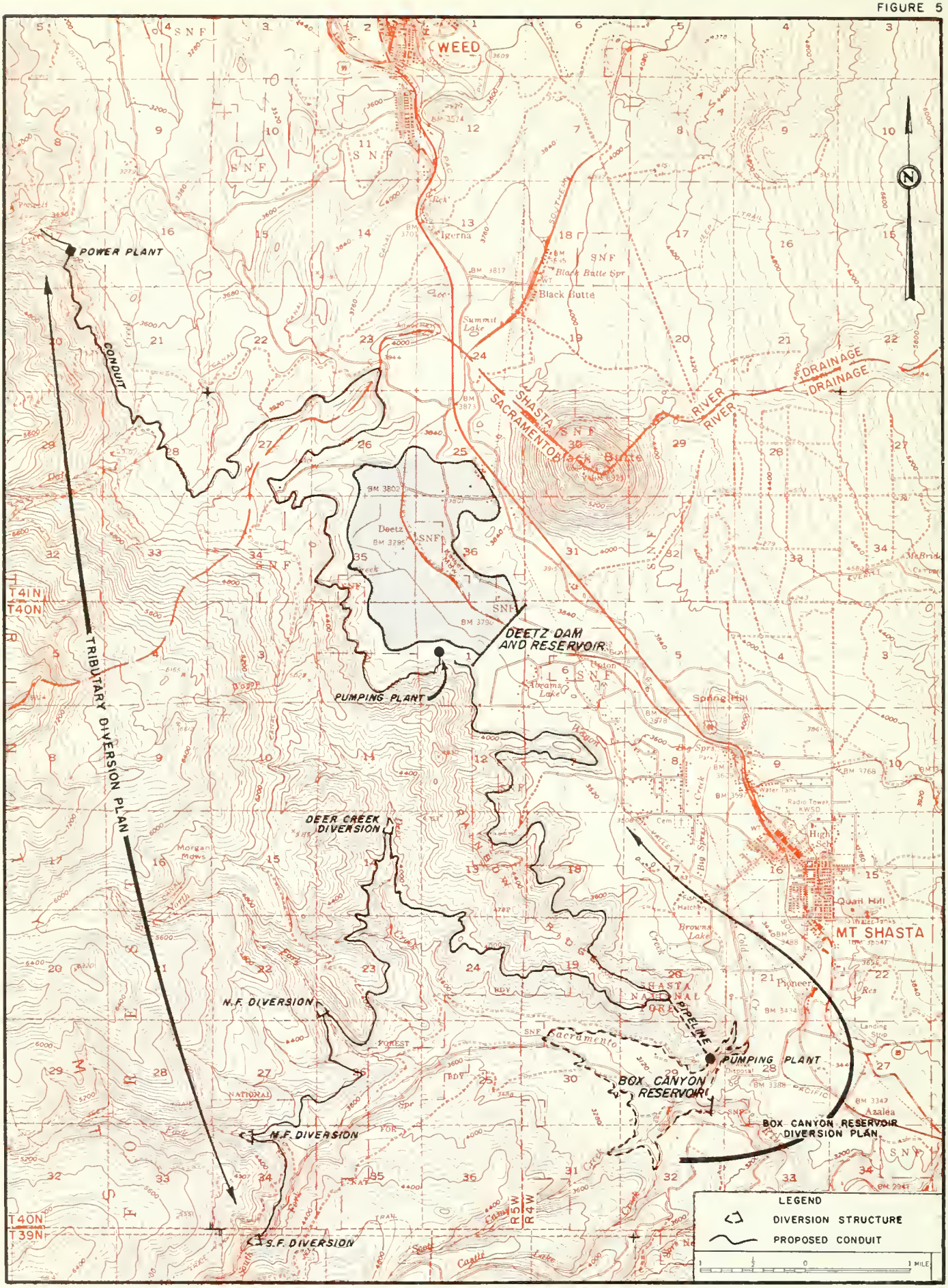
- A dam about 50 feet high and 3,000 feet long, containing 685,000 cubic yards of material, would be required at Deetz on Wagon Creek to form an offstream storage reservoir with sufficient capacity to store, for further diversion as needed during the irrigation season, the total annual winter diversion of approximately 30,000 acre-feet.

- A pumping plant would lift water from the offstream storage reservoir into a canal about 200 feet higher than the reservoir.

- A canal at approximately 4,000 feet elevation would convey water pumped from the reservoir northward about 11 miles to discharge through a powerplant into the Shasta River. The water would then be distributed for irrigation.

- A powerplant located at the terminal end of the canal (Section 17, T1N, R5W, M.D.B.&M.) could take advantage of a power drop of approximately 400 feet. This drop would generate energy equal to that required initially to lift the water into the canal, even allowing for transmission losses and the efficiencies of the pumping plant and powerplant.

Under the Tributary Diversion Plan, head losses in the conveyance system would require initial diversion on the South Fork at an approximate elevation of 3,900 feet. This elevation would limit the contributing drainage areas of the combined tributaries to a total of about 47 square miles. Table 14 shows the area of drainage basins above the several proposed diversion points. Flows from each tributary which would be exceeded 30 percent of the time during the four-month diversion period also are shown in Table 14. Estimates of these flows were computed from flow measurements by stream gages operated near the diversion sites during the period July 1960 through December 1960 and from estimated historical flows of the Sacramento River near Mt. Shasta. If facilities were provided to divert excess winter flows from each tributary, the average annual water supply available to Shasta Valley would be about 30,000 acre-feet. As previously shown, the estimated future impaired runoff of the Sacramento River at the Box Canyon site is 192,000 acre-feet per year. The diversion of



SHASTA VALLEY IRRIGATION WATER DELIVERY PLANS

30,000 acre-feet per year would leave an adequate supply for a reservoir at Box Canyon with the storage capacity of 30,000 acre-feet or greater.

As an alternative to the Tributary Diversion Plan, the Box Canyon Reservoir Diversion Plan considers pumping water directly from Box Canyon Reservoir into the conveyance system. For the purpose of comparing the two plans, the amount of the diversion was assumed to be the same for both. The engineering features of the two diversion plans would be essentially the same except that the diversion structures needed for the Tributary Diversion Plan would be omitted and the pumping plant from Box Canyon Reservoir to the canal would be added.

The following major works would comprise the Box Canyon Reservoir Diversion Plan:

- A pumping plant at Box Canyon Reservoir would lift water through approximately 4,000 feet of pipeline from an average water surface elevation of 3,150 feet at the reservoir into the conveyance system at elevation 3,840 feet.
- A conveyance system similar to that proposed for the Tributary Diversion Plan would begin at elevation 3,840 and end 8 miles northwest at the offstream storage reservoir.
- The offstream storage reservoir, pumping plant, canal, and powerplant would be similar to those proposed for the Tributary Diversion Plan, but would vary in size and requirements depending upon whether the plan was operated so that water from Box Canyon Reservoir would be pumped continuously or only during the irrigation season.

Figure 5 shows the locations of the structures required in both diversion plans.

Economic Justification. The proper determination of economic justification requires that the estimated benefits be compared to all costs of adding the purpose to the project. In this analysis, benefits were estimated for the assumed delivery of 30,000 acre-feet to Shasta Valley, but costs were estimated for only portions of the required diversion systems.

The cost estimates were discontinued when it became evident that the costs would exceed the benefits. The determination of the agricultural benefits is presented in the following section. Also presented is the cost estimate for a portion of each diversion plan.

(1) Benefits. Estimates of agricultural benefits were based on the results of economic studies made for Bulletin No. 87 "Shasta Valley Investigation." Data relating to crop patterns, crop yields, costs of farm production, and crop prices for the vicinity of Grenada were assumed to be applicable to the southern portion of Shasta Valley. The use of payment capacity for water as a measure of agricultural benefits would result in the most liberal estimate of benefits if the newly developed water were applied to undeveloped land or lands having very low net farm income under present conditions.

Values of estimated payment capacities under future conditions of crop pattern are presented in Table 15.

Table 15 also shows estimated benefits from an average annual irrigation water delivery of 30,000 acre-feet to Shasta Valley. The 1970 present worth value of total benefits was estimated to be $3,086,000, assuming interest at four percent and a repayment period of 50 years.

(2) Costs. The construction costs of the diversion structures - or pumping plant - and the conveyance system for both the Tributary Diversion Plan and the Box Canyon Reservoir Diversion Plan were estimated from the initial point of diversion to the proposed offstream storage reservoir at Deetz. The cost of diverting - or pumping - and conveying the water to the offstream storage reservoir was found to exceed the benefits in both plans.

Under the Tributary Diversion Plan, the costs of constructing diversion structures in four tributaries and approximately 19 miles of canal and flumes leading from the initial diversion on the South Fork of the Sacramento River to the offstream storage reservoir were estimated to be

TABLE 14

WATER SUPPLY AVAILABLE FOR
TRIBUTARY DIVERSION PLAN

Stream	Drainage area above diversion sites, 1/ in square miles	Flows exceeded 30% of time during diversion period 2/, in second-feet
Sacramento River		
South Fork	21.7	75
Middle Fork	12.2	45
North Fork	7.1	25
Deer Creek	2.4	10
Wagon Creek	3.3	12
TOTALS	46.7	167

1/ Figure 5 shows location of diversion sites.
2/ Diversion period is February through May.

TABLE 15

IRRIGATION BENEFIT IN SHASTA VALLEY WITH DIVERSION
OF 30,000 ACRE-FEET PER YEAR FROM SACRAMENTO RIVER BASIN

Year	Decade	Weighted average payment capacity, in dollars per acre-foot 1/		Irrigation benefit, 2/ in dollars	
		In first year of decade	Average for decade	Total for decade	Present worth
1970		3.55			
	1970-1979		3.83	1,149,000	944,000
1980		4.10			
	1980-1989		4.55	1,365,000	780,000
1990		5.00			
	1990-1999		5.33	1,599,000	580,000
2000		5.65			
	2000-2009		5.90	1,770,000	449,000
2010		6.15			
	2010-2019		6.48	1,944,000	333,000
2020		6.80			
Total present worth of irrigation benefit in 1970 =					3,086,000

1/ Assuming that additional water will change crop pattern and increase payment capacity.
2/ Assuming that payment capacity equals new net farm income, or irrigation benefit.

$2,400,000. The cost of the 50-foot high dam at Deetz was estimated to be $1,750,000. The quoted costs include 15 percent for engineering and 15 percent for contingencies, but do not include the considerable additional cost of land acquisition and relocation of facilities. The quoted costs alone, however, amount to $4,150,000, while the estimated benefit from water delivered to Shasta Valley during the 50-year repayment period would be only $3,086,000. No estimates of cost for the remainder of the required facilities for the Tributary Diversion Plan were made after the costs of the dam and diversion structures were determined to be in excess of the benefits.

Initial cost estimates for the Box Canyon Reservoir Diversion Plan showed that the pumping plant and pipeline alone would cost about $900,000. The cost per acre-foot of water delivered through only this portion of the system was found to be about $10 per acre-foot. The estimated average payment capacity in Shasta Valley during the 50-year repayment period, however, would be only $5.20 per acre-foot. Even the estimated maximum payment capacity reached in the year 2020 would be only $6.48 per acre-foot. Because the cost of water delivered through only this portion of the system would be greater per acre-foot than the payment capacity in Shasta Valley, no cost estimates were made for the remainder of the works in the Box Canyon Reservoir Diversion Plan.

Conclusions

Studies during this investigation indicate that demand for water for irrigation of lands along Wagon Creek can be more economically provided from ground water and tributary sources than from Box Canyon Reservoir.

Investigation also shows that transportation of irrigation water from the Sacramento River watershed into Shasta Valley is not economically justified by either the Tributary Diversion Plan or the Box Canyon Reservoir Diversion Plan because the cost of the diversion and conveyance works would be much greater than the possible benefits.

Therefore, it was concluded that conservation of water for the purpose of irrigation should not be included as a purpose in formulation of the Box Canyon Project.

Municipal and Industrial Uses

Consideration was given to the possibility of including the development of water supplies for municipal and industrial uses as a purpose in the proposed Box Canyon Project. This was done by estimating present and possible future demands for municipal and industrial water and determining whether these could be most economically met by the proposed project or by alternative sources.

Water Requirements

Estimates of use of municipal and industrial water under present conditions and water requirements for these uses under future anticipated conditions are discussed in the following sections.

Potential Service Areas. Potential areas for municipal and industrial water service from Box Canyon Reservoir would be the towns of Mt. Shasta City and Dunsmuir and their surrounding areas. The development of homes, motels, restaurants, and commercial establishments along the 6-mile portion of U. S. Highway 99 between Dunsmuir and Mt. Shasta City is beginning at the present time, and probably will continue in the future.

No large water using industries are located within this area although existing industries such as saw mills, beverage bottling plants, and the rail yards at Dunsmuir use moderate amounts of water. Use of water by the Southern Pacific Railroad has been reduced significantly by the conversion from steam to diesel equipment. According to local officials, whose comments have been supported by studies made during this investigation, water using industries have shown little interest in locating in this area. Therefore, the percentage

of industrial water use, as reflected in the present water consumption data, is assumed to remain about the same in the future.

The United States Census of 1960 reported that the population of Mt. Shasta City and surrounding area was 3,400 and that of Dunsmuir and surrounding area was 3,650. According to Department of Water Resources population projections for Siskiyou County, the estimated population of Mt. Shasta City would be 16,700 and that of Dunsmuir, 10,000, by the year 2020. The availability of developable land in the vicinity of Dunsmuir is expected to limit its future population.

Present Water Use. Mt. Shasta City presently obtains its municipal water supply through a city-owned system that makes use of springs located about 2 miles east of the town on the slopes of Mt. Shasta. No records of delivery are available for this system because the system is not metered. However, records for diversion near the springs were available for 1959 and 1960. The present average daily per capita use of water in Mt. Shasta City was estimated from municipal water use data from other towns in Northern California. The Northeastern Counties Investigation (Bulletin No. 58, 1960) reported that municipal water use of towns in mountainous areas is about 160 gallons per capita per day. Because the Mt. Shasta City system is not metered, use of the system was assumed to be somewhat greater than average, or about 200 gallons per capita per day. Total annual use of the approximately 2,000 persons served by the system was estimated to be about 140 million gallons, or 430 acre-feet. The remaining population is served by individual wells or springs.

Approximately 90 percent of the Dunsmuir population is supplied with water by the Dunsmuir Water Corporation, a private enterprise. Springs supplying this system are located in the Sacramento River Canyon about 2 miles upstream from Dunsmuir. The water system is metered and annual use figures were made available for this study. The average daily per capita water use rate for this

service was calculated from records of water sold and the population served. The average rate of water use is about 130 gallons per day per capita. If this rate is applied to the 3,200 estimated population served by all individuals and water agencies in Dunsmuir, the present annual water use in Dunsmuir is about 150 million gallons, or about 460 acre-feet.

Future Water Requirements. Municipal and industrial water requirements for both Mt. Shasta City and Dunsmuir in the year 2020 were estimated on the basis of expected per capita use rates and population projections for that date. The average daily per capita water use for urban mountainous areas in 2020 is estimated to be 250 gallons per day. This rate was used for Mt. Shasta City, but was reduced to 200 gallons per day per capita for Dunsmuir. With these rates of use and projected populations, the annual municipal and industrial water demand in Dunsmuir and Mt. Shasta City in 2020 is estimated to be 730 and 1,520 million gallons, respectively. These values represent about 2,300, and 4,600 acre-feet per year, respectively. A summary of estimated present and future municipal and industrial water requirements is presented in Table 16.

Present Water Supply

Municipal and industrial water for both Mt. Shasta City and Dunsmuir is supplied from springs by gravity flow while water for outlying areas is pumped from ground water. These sources provide an adequate supply of municipal water in both Mt. Shasta City and Dunsmuir at the present time. Because the water supply is derived from continually flowing springs, water is wasted during times of low water use. On the other hand, during times of high water use the supply from springs in Mt. Shasta is not sufficient and a well drilled in 1957 is used to augment the supply. However, the potential yield of this well, indicated by pumping tests, is only partially utilized.

The average annual production of the developed springs at Mt. Shasta City is estimated to be 215 million gallons and those serving Dunsmuir 200

TABLE 16

ESTIMATED PRESENT AND FUTURE MUNICIPAL AND
INDUSTRIAL WATER USE IN MT. SHASTA CITY AND DUNSMUIR

	Estimated 1960 development					Estimated 2020 development			
	Population served by water agencies	Per capita use, in gallons per day	Annual water use: In million gallons	Annual water use: In acre-feet	Annual production including waste, in million gallons	Population	Per capita use, in gallons per day	Annual water use: In million gallons	Annual water use: In acre-feet
Mt. Shasta City	2,000	200[1]	140	430	215	16,700	250	1,520	4,600
Dunsmuir	3,200	130[2]	150	460	200	10,000	200	730	2,300

1/ Estimated from average of similar communities.
2/ Calculated from records of Dunsmuir Water Corporation.

million gallons. Expressed in terms of acre-feet per year these values would be 660 and 610, respectively.

Future Water Supply

The estimated annual municipal and industrial water requirements for Mt. Shasta City in the year 2020 is about seven times the present production. Information acquired from the Mt. Shasta City Engineer and field inspection of the area indicate that this requirement can be met by development of springs in Big Canyon Creek and other parts of the general area and by full use of the present city well and the development of other wells when the demand arises.

The estimated annual municipal and industrial water requirement for Dunsmuir in 2020 is almost four times the present production. Several undeveloped springs with flows similar to those presently developed are within a few hundred feet of the present supply. The flow from these numerous springs forms Mossbrae Falls. Further development of the present springs and additional development of nearby springs when demand increases apparently will meet the estimated maximum water demand for Dunsmuir.

Outlying areas lying between Mt. Shasta City and Dunsmuir and served by neither were assumed to continue in the future to pump from ground water. In these areas pumping lifts from ground water presently vary from 0 to 125 feet.

Municipal Water Supply from Proposed Box Canyon Reservoir

If Box Canyon Reservoir were proposed as an alternative source of municipal water supply for Mt. Shasta City and Dunsmuir, their future demands for water and the cost of works to supply those demands would require consideration.

The investigation of present sources of water supply for these towns indicates that future demands can be met by expansion of present works and that

such expansion would be less costly than installation of works to convey water from Box Canyon Reservoir.

Delivery of water from Box Canyon Reservoir to Mt. Shasta City would require pumping lifts of from 100 to 300 feet whereas the springs presently used provide gravity feed. Although pumping from wells in the vicinity of Mt. Shasta City would require lifts of up to 125 feet, the length of pipeline from the wells would be less than from Box Canyon Reservoir. To supply Dunsmuir from Box Canyon Reservoir, a long pipeline or a pumping plant at the river would be required. After consideration of these factors, development of municipal water supplies from Box Canyon Reservoir appears to be more costly than further development of presently used sources.

Therefore, the following conclusions were reached: no foreseeable demand for municipal or industrial water from Box Canyon Reservoir would exist; the cost of developing water from Box Canyon Reservoir would exceed the cost of developing other sources; and the inclusion of this purpose in the Box Canyon Project could not be economically justified.

New Water Yield to Sacramento-San Joaquin Delta

The Sacramento-San Joaquin Delta is planned as the hub for distribution of water developed by the State Water Facilities. Under The California Water Plan, water presently wasted to the ocean by rivers in Northern and Central California will be conserved by reservoir storage, transported to the Delta, and from there distributed to areas of need.

If water could be stored in a reservoir at Box Canyon and released during critical periods to supply a portion of the future requirement to be diverted from the Delta, benefits from delivery of this water would accrue to the project.

Quantity of New Yield

Because Shasta Reservoir is located on the Sacramento River downstream from the Box Canyon Reservoir site, Box Canyon could take credit for developing new yield for the Delta Water Project only by storing water that would otherwise be wasted in surplus years. This storage would be carried over for long periods and released during the critical water supply years. The critical period of Shasta Reservoir, operated in conjunction with other reservoirs in the Central Valley Project, is the seven-year period represented by water years 1928-29 through 1934-35.

An operation study shows that 1,900,000 acre-feet would have been spilled from Shasta Reservoir in the 1927-28 water year, but that storage in Shasta Reservoir would have dropped to a low of 860,000 acre-feet during the seven-year critical period. If Box Canyon Reservoir could have impounded a portion of the water spilled by Shasta Reservoir in 1927-28, this impoundment could have been released during the carryover period, 1928-29 through 1934-35, to increase the annual firm yield* of Shasta Reservoir.

If Box Canyon Reservoir maintained 25,000 acre-feet of active storage capacity and were operated to release a net amount of 20,000 acre-feet in a period of two or three months during one low-supply year of the critical period, the reservoir could develop a firm annual yield of about 2,900 acre-feet. In addition to maintaining a minimum pool of 5,000 acre-feet for preservation of fishlife, an equal amount of 5,000 acre-feet would be retained to replace future evaporation that this method of operation would impose on Shasta Reservoir. For the remainder of the critical period, water that normally would flow into

* Firm yield is the maximum sustained rate of draft from a reservoir that could be maintained through a critically deficient water supply period to meet a given demand for water.

Shasta Reservoir would be retained in Box Canyon Reservoir throughout the recreation season but would be released each fall into Shasta Reservoir. This would create additional evaporation amounting to about 5,000 acre-feet over a seven-year period, which would be replaced by water held in Box Canyon Reservoir at the time of the conservation release.

Benefits

Completion of Box Canyon Reservoir by 1970 was assumed to increase the firm annual yield of the Delta by 2,900 acre-feet per year. No need for this amount would exist until at least 1982, because, according to the department's water demand and supply schedule, Oroville Reservoir, San Luis Reservoir, and the Delta Water Project will provide a surplus of water until that date. In about 1982 and subsequent years, water imported from the North Coast is scheduled to meet the next increment of demand and water from Box Canyon Reservoir logically might be fitted into the schedule. The benefits accruing to the Box Canyon Project over the 50-year repayment period were estimated to be $1,423,000 using a unit annual benefit of $40 per acre-foot. The latter value is currently (1962) being used in evaluation studies of the State Water Facilities, and is applicable to analyses of future projects which may develop water supplies for export from the Delta Pool.

Effect on Recreation Operation

A reasonable assumption resulting from the operation study is that water stored in Box Canyon Reservoir would have been used in 1928-29, the first year of the critical period, because Shasta Reservoir would have reached a low storage of 1,100,000 acre-feet on September 30 of that year. Box Canyon Reservoir could have been refilled with winter runoff during the following six years by "borrowing" water that would otherwise be stored in Shasta

Reservoir. Thus, a summer recreation pool could have been maintained during the critical period and reservoir recreation would not have been severely injured. At the same time reasonable winter fish maintenance flows could have been maintained. Each year of such a critical period, the entire 20,000 acre-feet of active storage would have to be released to Shasta Reservoir in the fall after the recreation season, during September, October or November, to replace water that would normally be stored in Shasta Reservoir. This annual fall release of 20,000 acre-feet would continue until Shasta Reservoir would spill again and new surplus water could be stored in Box Canyon Reservoir.

Lowering the reservoir to its minimum pool level each year during the critical period would result in a loss in recreation visitor-days. This loss was estimated to be the visitor-days attributable to fishing during the last 45 days of the season. About 4,500 visitor-days, on the average, would be lost during each of the seven years in which the release would be made. Assuming that the critical period would occur between the seventeenth and twenty-third years of project operation, the present worth of the loss in recreation benefits would be about $35,000. Extreme seasonal fluctuation of the reservoir between normal and minimum pool, however, would seriously curtail the fish populations making up the reservoir fishery which studies of recreation benefits assumed would be an essential part of the recreational attractiveness of Box Canyon Reservoir. Under such conditions of seasonal fluctuation, open season fishing could be maintained only by planting trout of catchable size.

It was assumed the fishing and recreation attraction could be maintained at the reservoir during the spring and summer, prior to the release of stored water, by an intensive fish planting program. The planting program would require about 225,000 catchable trout during the first year following the release of stored water. This number would increase throughout the seven-year

critical period and five years thereafter to 325,000. To estimate the cost of planting, it was assumed that the fish could be supplied by existing state facilities and from commercial hatcheries at a cost slightly higher than present state production costs. The present worth of the 12-year planting program was estimated to be $272,000.

An additional project cost would be required for a larger outlet at the dam to allow release of 20,000 acre-feet in a six-week period. The cost of increasing the outlet pipe diameter from 36 inches to 42 inches was estimated to be about $49,000.

Economic Justification

In considering economic justification of the water conservation purpose at Box Canyon Reservoir, the total benefits at the Delta of $1,423,000 would be limited by the least alternative cost. That is, the State could not spend more to develop water at this reservoir than at some alternative source. The Department of Water Resources is currently (1962) using an estimate of approximately $10 per acre-foot as the cost of replenishing the Delta Pool from several available sources of water supply. On this basis, the water conservation benefits, for purposes of cost allocation, would be limited to $356,000.

The economic justification of including this purpose may be determined by comparing the benefits limited by alternative cost to the separable cost of adding the project purpose and the cost of reservoir storage that may be allocated to conservation. The separable cost is the sum of the enlarged outlet, $49,000, and the fish planting program, $272,000; a total of $321,000. In addition, about $35,000 of joint reservoir cost would be allocated to this purpose on the basis of remaining benefits. Thus the total costs that may be allocated to water conservation would be $356,000, which is equal to the benefits

derived therefrom. A further consideration in adding this purpose would be the loss of about $35,000 in recreation benefits during the seven-year period of extreme fluctuation.

Because of the following reasons, benefits attributable to water conservation would be difficult to obtain.

Shasta Reservoir would have to be operated to make use of the release from Box Canyon Reservoir. The 20,000 acre-foot net release from Box Canyon Reservoir during the seven-year critical period must increase the release from Shasta Reservoir by 20,000 acre-feet during the same period. There must be some assurances that Shasta Reservoir or other reservoirs of the Central Valley Project or the State Water Facilities can be operated to tolerances of 2,900 acre-feet per year, and that the Bureau of Reclamation is willing to use the 20,000 acre-feet during the critical year in planning its operations.

The benefit was computed on the basis of first using the 2,900 acre-foot annual yield to the Delta in 1982. The actual year of initial use, however, depends entirely upon the abilities of other scheduled State Water Facilities (the Oroville and San Luis Reservoirs, the Delta Water Project, and the North Coast Imports) to supply the needs of the State as they then exist. Should water from Box Canyon Reservoir not be needed until 1990, for example, the benefits as computed on the basis of 1982 use would be too high.

CHAPTER IV. BOX CANYON PROJECT

Recreation and the development of additional yield for the State Water Facilities were shown in Chapter III to be the only separable purposes of the Box Canyon Project for which favorable benefit-cost ratios can be obtained. An economically justifiable project could be formulated either as: (1) a single-purpose recreation project, or (2) a multipurpose project to provide recreation and additional yield for the State Water Facilities. This chapter presents the engineering features and economic aspects of the single-purpose and multipurpose projects. In both cases, recreation remains as the primary purpose, and the same reservoir size was found to return maximum net recreation benefits. The following discussions present the engineering studies made to ascertain the engineering feasibility of Box Canyon Dam and Reservoir, the factors considered to design the projects and determine costs, and economic justification. For the multipurpose project, an allocation of costs is discussed.

Engineering and Geologic Studies

A dam and reservoir such as that suggested for Box Canyon would be considered to be engineeringly feasible under the following conditions:

- The water supply must be adequate in quantity and quality for the proposed size of the project.
- The dam and reservoir sites must be geologically suitable for the proposed structures and their uses.
- Design and construction possibilities must be such that the proposed uses of the project will be served efficiently and safely.
- Construction must be possible with available materials and present techniques at reasonable costs.

Comparison of Upper and Lower Damsites

The reach of the Sacramento River between the entrances of Wagon and Hey Springs Creeks is confined in a canyon with steep rock walls extending approximately 150 feet above streambed and overlain with soils of volcanic origin. Although an earth or rockfill dam could be constructed in several places throughout the three-quarter mile length of the canyon, topography provides two sites that appear most suitable for dams. These are designated as the upper and lower site on Plate 4, "Areal Geology." The upper damsite is located about 1,000 feet downstream from the Mt. Shasta City-Castle Lake road at a streambed elevation of 2,995 feet, USGS datum. The lower damsite is located about 4,000 feet farther downstream at a streambed elevation of 2,900 feet. The upper damsite would be suitable for a reservoir storage capacity up to 35,000 acre-feet and the lower site for a capacity up to 88,000 acre-feet. Both damsites are pictured in Illustration 6.

Photogrammetric procedures were used by the Department of Water Resources to prepare maps of the reservoir area and each damsite. The reservoir map was prepared at a scale of 1 inch equals 300 feet, with a contour interval of 10 feet. The damsite maps were prepared at a scale of 1 inch equals 150 feet, with a contour interval of 5 feet. During the investigation, use also was made of United States Geological Survey quadrangles, at a scale of 1:62,500 with a contour interval of 80 feet, and Army Map Service V502 maps, at a scale of 1:250,000 with a contour interval of 500 feet.

Because Box Canyon Reservoir would be used primarily for recreation, it was planned in terms of cost and size to be the smallest facility possible to serve adequately the predicted recreation use of the reservoir.

A detailed study was made of the ability of reservoirs of various sizes at the upper and lower damsites to attract and accommodate recreationists.

Box Canyon Damsites
(Looking Upstream)

This ability would vary because different water levels would affect the size of water surface and beach areas, the length and slope of shorelines, the depth and temperature of water, and the extent of shallow areas to provide the proper environment for the production of fish food. Recreation studies showed that a reservoir with a water surface elevation of 3,200 feet would create the most desirable setting.

The upper and lower sites were compared on the basis of a normal pool at elevation 3,200 feet. Development of a reservoir to this water surface elevation by a dam at the lower site would require about four times the volume of earth embankment required by a dam at the upper site, and therefore would necessitate a greater expenditure. A dam built to the same elevation at the lower site would create a reservoir of 46,000 acre-foot of storage capacity, but at a greater cost. At elevation 3,200 feet, maximum storage capacity at the upper damsite would be about 35,000 acre-feet -- well within storage requirements. The upper damsite, therefore, was selected to provide the smallest facility possible in terms of cost and size to serve adequately the predicted recreation use of the reservoir.

It was determined that the optimum size of reservoir as discussed above could be reduced to a normal pool elevation of 3,190 feet without a loss in either recreation attraction or benefit. This lower dam, which would effect a considerable saving in construction cost, would provide a reservoir with a surface area of 485 acres, a capacity of 30,000 acre-feet, and a shoreline of approximately 7 miles. In analyzing the size of reservoir needed to fulfill the water conservation purpose to develop additional yield to the State Water Facilities, it was found that the benefits accruing to this purpose would not justify construction of a reservoir larger than the minimum size needed for recreation.

Following geologic investigation, preliminary engineering designs for various sizes of both zoned earthfill and concrete arch dams at the upper damsite showed that a zoned earthfill dam would be more economical than a concrete arch dam. Therefore, a zoned earthfill dam was selected as the more desirable for the Box Canyon Project.

Geology of the Upper Damsite

During geologic exploration at the upper damsite, surface materials were mapped and classified. A seismic survey and a field permeability test were made, and eight holes, varying in depth from 6 to 66 feet, were bored with an auger drill. This exploration showed that volcanic rock forms the lower portion of both abutments. The volcanic rock is overlain by lake deposits and glacial drift on the left abutment and by red clay material of volcanic origin on the right abutment. Illustration 7 pictures both abutments. Possible leakage through the sediments of the left abutment and through those sediments underlying the volcanic rock creates the principal foundation problem. Prior to final planning and design of a dam at this site, it is recommended that the geology and foundation conditions be thoroughly investigated by core drilling, water pressure testing, field permeability testing of abutment areas, and adequate construction materials drilling, sampling, and testing.

Foundation conditions which particularly would affect a zoned earthfill dam at the upper damsite are discussed under the headings: Right Abutment, Channel, Left Abutment, and Spillway. Additional conditions which particularly would affect a concrete arch dam, had such been chosen for the Box Canyon Project, are discussed separately and more briefly.

Right Abutment. The portion of the right abutment below elevation 3,150 feet is a cliff of volcanic rock, nearly vertical and at places overhanging. Above this rock are deposits of a red clay material of volcanic

Upper Damsite
(Looking Downstream)

origin. Subsurface information obtained from several auger holes[1] was used to locate the contact between the rock and the red clay material. Above elevation 3,150, the slope of the rock flattens abruptly to about 10 degrees, continues to rise beneath the soil cover to about elevation 3,190, and thereafter begins to fall away. Auguer hole B-A8, about 250 feet from the rim of the canyon, shows that the firm rock surface has dropped back to about elevation 3,150. Plate 5, "Geologic Sections and Auger Hole Logs," presents a cross section of the damsite showing this contact.

Vertical joints both perpendicular and parallel to the stream channel divide the rock of the right abutment into columnar blocks several feet or more across. These joints are open, have small flows of water coming from them, and are believed to be filled with clay. The joints are closed in the channel and may close with depth in the abutment. Clay filled joints present no structural problems for an earthfill dam, although some grouting of joints in the abutment may be necessary to prevent leakage.

A good location for a fill dam is shown on Plate 4 as line A-A'. Special compaction procedures would be necessary to assure a water-tight contact between the impervious core and the steep lower portion of the right abutment. Stripping for an earthfill dam would vary between zero to 15 feet on the upper portion of the right abutment and shaping of hard, irregular rock would be required on the lower portion of the abutment.

Channel Section. At the upper damsite, the channel is about 70 feet wide and is bounded by nearly vertical to overhanging rock cliffs. Hard rock outcrops are present in the channel, sometimes covered by small discontinuous accumulations of gravel and talus. Very little foundation preparation would be required beyond removal of the gravel and talus, and the shaping of the bedrock.

1/ The locations of the holes, B-A8 through B-A12, are shown on Plates 4 and 5.

Left Abutment. Topographically, the left abutment, much lower than the right, would limit an earthfill dam to elevation 3,220 feet. The left abutment is composed of volcanic rock as described for the right abutment and overlain by glacial drift and lake deposits. The contact with volcanic rock begins at about elevation 3,150 and is shown on Plate 5, Section A-A'. The average slope of the left abutment is less than that of the right abutment. Slope of the volcanic rock varies from vertical to 45 degrees; that of the glacial drift overlying the rock averages about 25 degrees.

Two auger holes, B-A4 and B-A5, were drilled in the glacial drift. A field permeability test was run on hole B-A4. The field permeability test indicated a permeability of about 5 feet per day. Samples were taken from both holes for the purpose of laboratory permeability tests of remolded samples. The tests showed that the glacial drift material is quite pervious in the natural state and that some treatment of this material might be required to prevent reservoir leakage and possible failure of the left abutment.

Spillway. Spillways at various elevations through both the right and left abutments were considered and a site on the right abutment was chosen. A spillway on the right abutment would be cut through the red clay material and could be founded on the solid volcanic rock at elevations below 3,175 feet. Such a solid foundation is preferable for a spillway. On the left abutment, the spillway cut would be entirely in glacial drift material at elevations above 3,160 feet. Concrete lining of the spillway would be necessary to prevent erosion damage to the spillway channel on either abutment.

Concrete Arch Dam. The upper site would provide a good location for a concrete arch dam slightly upstream from that selected for an earthfill damsite. Foundation conditions along the left and right abutments and the channel section are the same as at the proposed location of the earthfill dam. Weathering,

topography, and jointing are important factors which would affect a concrete arch dam. Deep weathering of the volcanic rock was indicated by the low seismic velocities along line F shown on Plate 4. Section C-C', Plate 5, shows a geologic cross section of the concrete arch damsite. Although the slope of the rock drops off rapidly above elevation 3,135 on the left abutment, an artificial concrete abutment could be provided for a dam with its crest at elevation 3,160. To construct a higher dam, topography of the right abutment would also require addition of an expensive artificial abutment. Furthermore, the jointing which is present in both abutments presents a very serious problem and casts doubt on the ability of the foundation to support an arch structure. The first step toward effective grouting of these joints--washing out the clay which may fill them--may be very difficult to accomplish. Proper evaluation of the problem of preparing the foundation for a concrete arch dam would require further exploration of the jointing.

Construction Materials

A sufficient quantity of material required for a zoned earthfill dam is available within 2 miles of the damsite. Two general types of material, pervious and impervious, are required for construction of a zoned earthfill dam. Pervious material through which water will pass freely provides drainage and stability to the structure; whereas impervious material which restricts the passage of water is used as a core in the dam to prevent excessive leakage.

Pervious Material. Materials satisfactory for the pervious sections of the dam are available from three sources. These are:

- Streambed gravels deposited immediately upstream from the damsite in the reservoir area.
- Granitic rock which outcrops on the south side of Ney Springs Creek.
- Volcanic rock which outcrops on the north side of Ney Springs Creek.

The locations of these sources are shown on Plate 6, "Location of Construction Materials," as B3, Q2, and Q1, respectively.

Quality of the three materials as indicated by laboratory tests of soundness, specific gravity, and absorption was found to be nearly equal. The streambed gravels were chosen for the pervious sections of the dam because of their proximity to the damsite and their ease of excavation. These factors would result in lower construction costs than would occur were use made of either of the alternative borrow sites. It is estimated that there are over 2,000,000 cubic yards of streambed gravels available.

Concrete Aggregate. Possible sources of concrete aggregate would be the same as those for the pervious material. However, sufficient tests to determine the suitability of these sources for concrete aggregate were not performed during this investigation.

Impervious Material. Laboratory tests were conducted on two sources of impervious borrow material overlying the volcanic rock of the abutments. These sources are the glacial drift material of the left abutment, and the red clay material of the right abutment. Tests of the glacial drift material from the left abutment indicated permeability rates ranging from 5 feet per day for material in the natural state to 0.032 feet per day for samples compacted by application of 20,000 foot-pounds per cubic foot. No permeability tests were performed on the red clay material from the right abutment, but the permeability rate certainly would be much lower than that for the left abutment material. Tests indicate both materials would be suitable for the impervious core if proper compaction methods were utilized. Properties of each material are presented in Table 17.

TABLE 17

PROPERTIES OF IMPERVIOUS MATERIAL

Material	Plasticity index	Specific gravity	Angle of internal friction
Left abutment, glacial drift	15	2.67	35°
Right abutment, red clay	26	2.80	20°

Because the steep abutments could cause differential settlement, the more plastic, clay material from the right abutment, was chosen as the core material.

Box Canyon Project

The three main elements of the Box Canyon Project, formulated either as a single-purpose or a multipurpose project, are: (1) the dam and appurtenant structures, (2) the reservoir, and (3) the recreation facilities. The dam and appurtenant structures were designed, in accordance with standard engineering principles, to satisfy the recreation purposes of the project by use of the most economical combination of embankment, spillway, and outlet works. Foundation conditions received adequate consideration for planning cost estimates. The dam was designed to be constructed of available natural materials and the spillway, to pass the probable maximum flood* without damage to the dam. Recreation facilities were designed to meet standards established by the Department of Water Resources and the Department of Parks and Recreation.

* This is the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the drainage basin.

The features of the Box Canyon Project reasonably represent those which would be selected for construction to meet the intended purposes of the project. Further exploration of foundation conditions at the damsite, more extensive tests of borrow material, and more thorough design analyses would be necessary before actual construction. Although such further study might result in some changes in design, the estimated costs of the project are believed adequate for comparison with the estimated benefits accruing to the project. Such comparison is necessary to the evaluation of the economic justification of the project.

Capital costs of the project would include the costs of acquiring the dam and reservoir sites, of constructing the dam and appurtenances, of acquiring the necessary recreation areas and constructing recreation facilities, and of relocating all public utilities. Estimates of capital costs are based on unit prices that prevailed in October 1961, and allow 15 percent for construction contingencies, 15 percent for engineering and administration, and 4 percent a year for interest during construction.

Annual costs include costs of operation, maintenance, replacement, and general expense, interest at 4 percent a year on the capital investment, and repayment throughout 50 years at 4 percent interest.

Dam and Appurtenant Structures

The zoned earthfill dam selected to fulfill requirements of the project and its site would rise 220 feet above streambed to a crest at elevation 3,215 feet above mean sea level and would contain 680,000 cubic yards of fill material. The same features of the dam and spillway would be used for either the multipurpose or single-purpose project. The multipurpose project would require a larger outlet system. Pertinent features of the dam and reservoir

are given in Table 18. Table 19 itemizes costs used to estimate total costs of the dam, reservoir, and appurtenant structures required for a single-purpose recreation project; and Table 20 itemizes these costs for the multipurpose project.

Embankment. The embankment section would contain a moderately thick impervious core of red clay material obtained from the spillway excavation and from a borrow area adjacent to the right abutment. The impervious core would be flanked on each side by transition zones constructed of selected glacial drift material from sources in the reservoir area adjacent to the left abutment. Overlying the transition zone would be a pervious embankment zone of natural sand, gravel, and cobbles. Sufficient quantity of this material is present in the reservoir area immediately upstream from the dam. Plate 7, "Box Canyon Dam: General Plan and Sections," shows slopes and positions of the various zones within the embankment section.

The steepness of the canyon walls at the damsite would necessitate severe shaping of the abutments under the core and transition zones to reduce the danger of transverse cracking within the zones. The red clay used in the core would further reduce danger of cracking because of its plastic qualities.

Extensive testing and exploration to determine leakage and stability characteristics of the left abutment under sustained water loads will be necessary before proper treatment of this abutment can be designed. However, for the purpose of this report, an impervious blanket was assumed to be required over an area extending from the dam approximately 1,500 feet up Wagon Creek and from the Wagon Creek streambed up to elevation 3,200 feet. The problem area is delineated on Plate 7. The area has a natural average slope of less than 2:1. Prior to blanketing, this slope would be stabilized to prevent possible sloughing under long term saturation. Stabilization would require that the slope be flattened to 3:1. Details of the slope treatment are also presented on Plate 7.

TABLE 18

FEATURES OF BOX CANYON DAM AND RESERVOIR

Dam and Reservoir	
Location	SE ¼, Section 29, T4ON, R4W, MDB&M
Stream	Sacramento River
Reservoir	
Drainage area in square miles	122
Elevation, in feet USGS datum	
Maximum water surface	3,210
Normal water surface	3,190
Minimum pool	3,100
Storage capacity at normal water surface, in acre-feet	30,000
Reservoir area at normal water surface, in acres	485
Dam Structure	
Type	Zoned earthfill
Crest elevation, in feet USGS datum	3,215
Streambed elevation, in feet USGS datum	2,995
Height of dam above streambed, in feet	220
Crest length, in feet	1,250
Crest width, in feet	30
Slopes	
Upstream face, above berm at elevation 3,150	2:1
Upstream face, below berm at elevation 3,150	2.5:1
Downstream face	2:1
Total embankment, in cubic yards	680,000
Spillway	
Type	Ogee
Crest elevation, in feet USGS datum	3,190
Crest length, in feet	125
Design flood surcharge head, in feet	20
Design flood residual freeboard, in feet	5
Design capacity, in second-feet	43,000
Energy dissipator	Flip bucket
Outlet Works for Single-Purpose Project	
Type	Cut and cover
Diameter, in inches	36
Maximum discharge at normal pool, in second-feet	316
High pressure slide gate, dimensions in feet	3.5 x 3.5
Regulating valve size, in inches	30
Outlet Works for Multipurpose Project	
Type	Cut and cover
Diameter, in inches	42
Maximum discharge at normal pool, in second-feet	365
High pressure slide gate, dimensions in feet	4.0 x 4.0
Regulating valve size, in inches	36

TABLE 19

SINGLE-PURPOSE PROJECT
ESTIMATED COST OF BOX CANYON DAM AND RESERVOIR
(Based on prices prevailing in 1961)

Dam crest elevation: 3,215 feet, USGS datum
Spillway crest elevation: 3,190 feet, USGS datum
Height of dam crest above streambed: 220 feet

Item	Unit	Quantity	Unit price	Total cost	
Dam					
Diversion and care of stream	lump sum			$ 22,000	
Excavation, foundation stripping and core trench above elevation 3,150 ft.	cu yd	31,600	$ .75	23,700	
Excavation, rock; abutment shaping	cu yd	24,300	6.00	145,800	
Drilling and grouting	lin ft	6,000	10.00	60,000	
Stripping impervious borrow pit	cu yd	75,000	.35	26,300	
Borrow excavation					
Impervious	cu yd	97,500	.78	76,100	
Pervious	cu yd	401,700	.70	281,200	
Transition	cu yd	100,600	.78	78,500	
Embankment					
Impervious--from borrow	cu yd	78,000	.20	15,600	
Impervious--from spillway salvage	cu yd	83,000	.25	20,800	
Pervious	cu yd	401,700	.10	40,200	
Transition	cu yd	77,400	.20	15,500	
Rock from spillway salvage	cu yd	40,000	.50	20,000	
Special compaction	cu yd	5,900	2.00	11,800	
					$ 837,500
Impervious Blanket					
Site preparation	lump sum			33,700	
Bank stabilization					
Excavate and compact	cu yd	174,800	.56	97,900	
Impervious borrow	cu yd	36,100	.74	26,700	
Impervious blanket	cu yd	72,000	.74	53,300	
Slope protection	cu yd	111,600	.76	84,800	
Riprap	cu yd	4,000	2.00	8,000	
					$ 304,400
Spillway					
Excavation, common	cu yd	110,000	1.17	128,700	
Excavation, rock	cu yd	48,000	2.50	120,000	
Structural backfill	cu yd	2,750	5.00	14,000	
Concrete weir and bucket	cu yd	1,760	50.00	88,000	
Concrete walls	cu yd	1,950	80.00	156,000	
Concrete chute floor	cu yd	1,830	45.00	82,400	
Cement	bbl	6,270	5.00	31,400	
Anchor bars--drill	lin ft	1,440	3.00	4,300	
Reinforcing steel	lb	503,000	.15	75,400	
Drains	lin ft	3,300	4.50	14,800	
Bridge	lump sum			56,000	
					$ 771,000

TABLE 19

SINGLE-PURPOSE PROJECT
ESTIMATED COST OF BOX CANYON DAM AND RESERVOIR
(Continued)

Spillway capacity with 5-foot freeboard: 43,000 second-feet
Reservoir capacity at spillway crest: 30,000 acre-feet

Item	Unit	Quantity	Unit price	Total cost	
Outlet Works					
Excavation, rock	cu yd	300	$ 5.00	$ 1,500	
Concrete--conduit	cu yd	904	40.00	36,200	
Concrete--intake tower and valve house	cu yd	304	70.00	23,800	
Cement	bbl	1,724	5.00	8,600	
Reinforcing steel	lb	175,600	.15	26,300	
Steel pipe	lb	98,400	.50	49,200	
Steel trash rack	lb	4,800	.50	2,400	
30-inch Howell Bunger type valve	ea	1	20,000.00	20,000	
3.5' x 3.5' H.P. slide gate	ea	1	33,000.00	33,000	
					$ 201,000
Subtotal					$2,113,900
Engineering and administration					317,100
Contingencies					365,000
Interest during construction at 4 percent					112,000
TOTAL COST OF DAM					$2,908,000
Reservoir					
Clearing to elevation 3,195	ac	380	$ 263.00	$ 100,000	
Road relocation	mi	4.2	45,500.00	191,000	
Sewage plant relocation	lump sum			10,000	
Land acquisition	lump sum			374,800	
					$ 675,800
Engineering and administration					45,200
Contingencies					51,900
Acquisition contingencies					75,000
Interest during construction at 4 percent					33,900
TOTAL COST OF RESERVOIR					$ 881,800
TOTAL CAPITAL COST, DAM AND RESERVOIR, SINGLE-PURPOSE PROJECT					$3,789,800

TABLE 20

MULTIPURPOSE PROJECT
ESTIMATED COST OF BOX CANYON DAM AND RESERVOIR
(Based on prices prevailing in 1961)

Dam crest elevation: 3,215 feet, USGS datum
Spillway crest elevation: 3,190 feet, USGS datum
Height of dam crest above streambed: 220 feet
Spillway capacity with 5-foot freeboard: 43,000 second-feet
Reservoir capacity at spillway crest: 30,000 acre-feet

Item	Unit	Quantity	Unit price	Total cost
Dam		(See Table 19)		
Subtotal				$ 837,500
Impervious Blanket		(See Table 19)		
Subtotal				304,400
Spillway		(See Table 19)		
Subtotal				771,000
Outlet Works				
Excavation, rock	cu yd	400	$ 5.00	$ 2,000
Concrete--conduit	cu yd	1,034	40.00	41,700
Concrete--intake tower and valve house	cu yd	359	70.00	25,100
Cement	bbl	1,929	5.00	9,600
Reinforcing steel	lb	198,000	.15	29,700
Steel pipe	lb	102,830	.50	51,400
Steel trash rack	lb	6,550	.50	3,300
36-inch Howell Bunger type valve	ea	1	29,000.00	29,000
4' x 4' H.P. slide gate	ea	1	45,000.00	45,000
				$ 236,900
Subtotal				$2,149,800
Engineering and administration				322,500
Contingencies				370,800
Interest during construction at 4 percent				113,700
TOTAL COST OF DAM				$2,957,000
TOTAL COST OF RESERVOIR		(See Table 19)		881,800
TOTAL CAPITAL COST, DAM AND RESERVOIR, MULTIPURPOSE PROJECT				$3,838,800

Spillway. An uncontrolled spillway located in the right abutment would consist of an unlined approach channel, a 125-foot long concrete ogee weir with the crest at elevation 3,190 and a 500-foot long, converging concrete-lined chute. A flip bucket at the end of the chute would break the force of the water entering the stream channel. The spillway is designed for a maximum discharge of 43,000 second-feet with a surcharge of 20 feet to allow a residual freeboard of 5 feet on the dam. This maximum discharge capacity was determined from a flood routing study based on reservoir inflow from the maximum probable flood. No reduction in peak flow would be realized from surcharge storage during the maximum probable flood.

Outlet Works, Single-Purpose Project. A cut and cover outlet works, consisting of an outlet structure, an intake structure, and a 36-inch diameter steel-lined concrete conduit, 1,065 feet long, would be constructed in the stream channel. The conduit was designed to discharge 300 second-feet under a minimum head of 150 feet. The outlet works would be used for normal stream maintenance releases and also for diversion of the stream during construction of the dam.

The intake structure, a reinforced concrete tower rising 28 feet above streambed, would provide for possible reservoir sedimentation. A hydraulically operated high pressure slide gate would be installed near the upstream end of the conduit to provide for emergency closure. An outlet regulating valve would be installed at the downstream end of the conduit to dissipate energy and to provide regulated stream releases. A 10-inch bypass line with necessary control equipment would be installed parallel to the main conduit to guarantee a source of water for the downstream fishery in case of emergency closure of the main outlet works.

A gated outlet through the base of the spillway weir would be provided to release up to 50 second-feet of water from the upper portion of the reservoir.

This water would be used for temperature control of the downstream fishery maintenance release.

Outlet Works, Multipurpose Project

A cut and cover outlet works, consisting of an intake structure, a 42-inch steel-lined concrete conduit, 1,065 feet long, and an outlet structure would be constructed in the stream channel. The outlet works would be used for normal stream releases, release of water during the critical period to increase Delta yield, and also for diversion of streamflow during construction of the dam. The conduit was designed to discharge a total of 28,800 acre-feet of water from the reservoir during a period of 45 days under a head varying from 195 feet at the beginning of the period to 110 feet at the end of the period.

The intake structure, bypass line for emergency release of water for streamflow maintenance, and the outlet structure would remain the same as the smaller diameter outlet works estimated for the single-purpose recreation project. However, the emergency slide gate would be increased in size to 4 feet by 4 feet, and the outlet regulating valve would be 36 inches in diameter.

Reservoir Land Acquisition

A total area of 2,088 acres was considered as the minimum reservoir recreation project area to provide for the dam and reservoir and for lands for recreation facilities to meet the estimated water-associated recreation demands. This area, designated as the proposed recreation area on Plate 3, was used for the purpose of cost estimates presented herein to determine economic justification of the Box Canyon Project. However, it was determined in consultation with the Department of Parks and Recreation that an area surrounding the reservoir suitable for establishment as part of the State Park System would comprise about 4,800 acres. This larger area would fulfill state park standards by joining U. S. Forest Service lands to the south and west of the recreation project area and by including lands within the watershed along Rainbow Ridge to the north.

Lands proposed for acquisition for the reservoir recreation project area are discussed in the following paragraphs. Additional lands that would be desirable for a state park unit are discussed at the end of this chapter under the heading "State Park System Development."

The area subject to inundation by Box Canyon Reservoir includes two farms which contain approximately 300 acres of developed agricultural land. The balance of the inundated area and the other land included in the acquisition for recreation purposes and buffer zones is undeveloped, cut-over timberland. This land includes 60 acres in Section 28, Township 40 North, Range 9 West, planned as the site for relocation of the Mt. Shasta City sewage oxidation ponds. The present sewage ponds lie at the site of the left abutment of the proposed Box Canyon Dam. The area designated for relocation of the oxidation ponds is shown on Plate 3.

Of the lands proposed for acquisition, about 700 acres adjacent to the reservoir would be suitable for recreation development to fulfill the estimated water-associated recreation needs. Of this acreage, about 400 acres would be best suited for development of campsites and about 200 acres, for development of picnic areas. The remainder of the recreation area could be developed for beach areas, boat launching ramps, concession areas, overlook areas, and access roads. Areas best suited for these various types of recreation development are delineated on Plate 3.

The remainder of the acquired land, about 850 acres, would be neither inundated by the reservoir nor designated for recreation development and should be preserved as natural buffer area and to provide public access to adjoining U. S. Forest Service lands.

Property descriptions and information on land ownership were supplied by the Siskiyou County Assessor. The value of each tract was determined by a market analysis method which compared the land with similar property which had been involved in recent sales during 1959 and 1960. The Siskiyou County

Recorder and local real estate agencies supplied data on such sales of properties in or near the area involved.

The cost of acquisition of the 2,088 acres is estimated to be $450,000 and includes severance damages, acquisition overhead costs, and contingencies.

In the reservoir area, there are no public utilities which would require relocation. The estimated cost of constructing the new facilities required as a result of the assumed relocation of the Mt. Shasta City sewage oxidation ponds would be $10,000. The Mt. Shasta City dump is adjacent to the present sewage pond area and also would require relocation. Its cost of relocation was considered minor and was not included as a project cost.

The Mt. Shasta City-Castle Lake county road through the reservoir area and a private logging road presently parallel to the Sacramento River in the reservoir area would require relocation. The county road would be routed out of the reservoir area by way of the dam crest. The logging road would be routed around the south side of the reservoir and would be used for access to the recreation areas planned for the south and east shores of the reservoir. Plate 3 shows the planned locations of these two roads. The total cost of the 4.2 miles requiring relocation would be an estimated $253,000. An all-weather, asphalt surface would be provided.

Estimated costs of acquiring the necessary land for the Box Canyon Project and of relocating the sewage ponds and the two roads have been shown in Table 19.

In addition to the 2,088 acres needed for the proposed recreation area, the Department of Fish and Game has recommended 100 acres be provided to replace intermediate deer range which would be inundated by the reservoir. The loss of this range would be detrimental to the migratory deer herd, according to a study conducted by the Department of Fish and Game, to determine probable effects of Box Canyon Reservoir on the fish and wildlife

resources of the Upper Sacramento River Basin. As selected for planning purposes, this 100-acre parcel would lie in the NW¼ of Section 32, T40N, R4W, and would be adjacent to the project acquisition boundary. The cost of acquiring this land was estimated to be $10,000.

Recreation Facilities

Estimates of the extent of recreation facilities needed at Box Canyon Reservoir to meet the projected demand were made to ascertain that the site could be developed to meet demand and to estimate the cost of recreation facilities.

Development of suitable facilities for camping, picnicking, boating, and swimming would be desirable in the areas delineated on Plate 3. Selection of these areas followed inspection of possible sites and consideration of their suitability in terms of use and development. Although a substantially different plan of development could result from the more detailed studies of the site and facilities which would be required prior to actual construction, the plan presented is believed to represent adequately the costs of development.

Estimated demand for recreation facilities would require initial installation of 245 campsites, 50 picnic units, 1 beach area, a boat launching ramp, concession area, and an overlook area for sightseeing. In addition, a water supply would be developed, sanitary facilities installed, access roads constructed, and other items required for proper operation and maintenance of the recreation facilities would be provided.

Estimated recreation demand in the year 2020 would require a total of 870 camp units, 300 picnic units and expansion of the water system, sanitary facilities, beach areas, and concession areas.

Table 9 (page 45) presents a schedule of costs for installation of recreation facilities to standards used by the State Park System. The capital cost of the initial facilities was estimated to be $968,000 and future installations would require capital expenditures of $2,705,000 as shown in Table 9.

The total present worth of installation of recreation facilities is $1,990,000. The cost of operation, maintenance, and replacement of the initial recreation facilities was estimated to be $50,000 per year. This would increase to $204,000 when all of the recreation facilities would be installed. The total present worth of operating, maintenance, and replacement over the 50-year period would be $2,117,000.

The total present worth of operation and maintenance of the 100 acres of deer range recommended by the Department of Fish and Game is $46,000. The initial cost of improving this range is estimated to be $20,000.

Summary of Project Costs

The estimated costs of the Box Canyon Project as formulated for single-purpose and multipurpose projects are presented in Tables 21 and 22, respectively. The costs of the project have been shown as initial and future expenditures. Initial expenditures represent the costs of construction required to build the project and put it into the first year of operation. Future costs, expressed in terms of present worth, are additional costs required during the 50-year economic life of the project, and include annual expense for operation, maintenance and replacement, and costs of installation of future recreation facilities. The sum of initial and future expenditures represents total project costs that may be compared to total project benefits.

The single-purpose recreation project was estimated to have initial costs of $4,788,000 and total project costs reduced to a 1970 present worth value of $8,403,000. The average annual equivalent cost over the 50-year period with interest at 4 percent is $391,000.

The multipurpose recreation and conservation project was estimated to have initial costs of $4,837,000 and total project costs reduced to a 1970 present worth value of $8,724,000. The average annual equivalent cost over the 50-year period with interest at 4 percent is $406,000.

TABLE 21

SUMMARY OF SINGLE-PURPOSE BOX CANYON PROJECT COSTS

Item	Capital Cost: Construction cost	Capital Cost: Engineering, administration, contingencies & interest during construction	Present worth of capital cost	Average annual equivalent of present worth
Initial Expenditures				
Dam and appurtenances	$2,114,000	$ 794,000	$2,908,000	$135,400
Reservoir	676,000	206,000	882,000	41,100
Recreation facilities	968,000	*	968,000	45,100
Replacement deer range	30,000	*	30,000	1,400
Subtotal	$3,788,000	$1,000,000	$4,788,000	$223,000
Future Expenditures				
Recreation facilities	2,705,000	*	1,022,000	47,600
Operation, maintenance, replacement & general expense of dam	---	---	430,000**	20,000
Operation, maintenance & replacement of recreation facilities	---	---	2,117,000**	98,500
Operation and maintenance of deer range	---	---	46,000**	2,100
Subtotal	$2,705,000		$3,615,000	$168,200
TOTAL	$6,493,000	$1,000,000	$8,403,000	$391,200

* Included in construction cost
**Total present worth of annual expenditures

TABLE 22

SUMMARY OF MULTIPURPOSE BOX CANYON PROJECT COSTS

Item	Capital Cost: Construction cost	Capital Cost: Engineering, administration, contingencies & interest during construction	Present worth of capital cost	Average annual equivalent of present worth
Initial Expenditures				
Dam and appurtenances	$2,149,000	$ 808,000	$2,957,000	$137,600
Reservoir	676,000	206,000	882,000	41,100
Recreation facilities	968,000	*	968,000	45,100
Replacement deer range	30,000	*	30,000	1,400
Subtotal	$3,823,000	$1,014,000	$4,837,000	$225,200
Future Expenditures				
Recreation facilities	2,705,000	*	1,022,000	47,600
Operation, maintenance, replacement & general expense of dam	---	---	430,000**	20,000
Operation, maintenance & replacement of recreation facilities	---	---	2,117,000**	98,500
Operation and maintenance of deer range	---	---	46,000**	2,100
Catchable trout planting program	---	---	272,000**	12,700
Subtotal	$2,705,000		$3,887,000	$180,900
TOTAL	$6,528,000	$1,014,000	$8,724,000	$406,100

* Included in construction cost
**Total present worth of annual expenditures

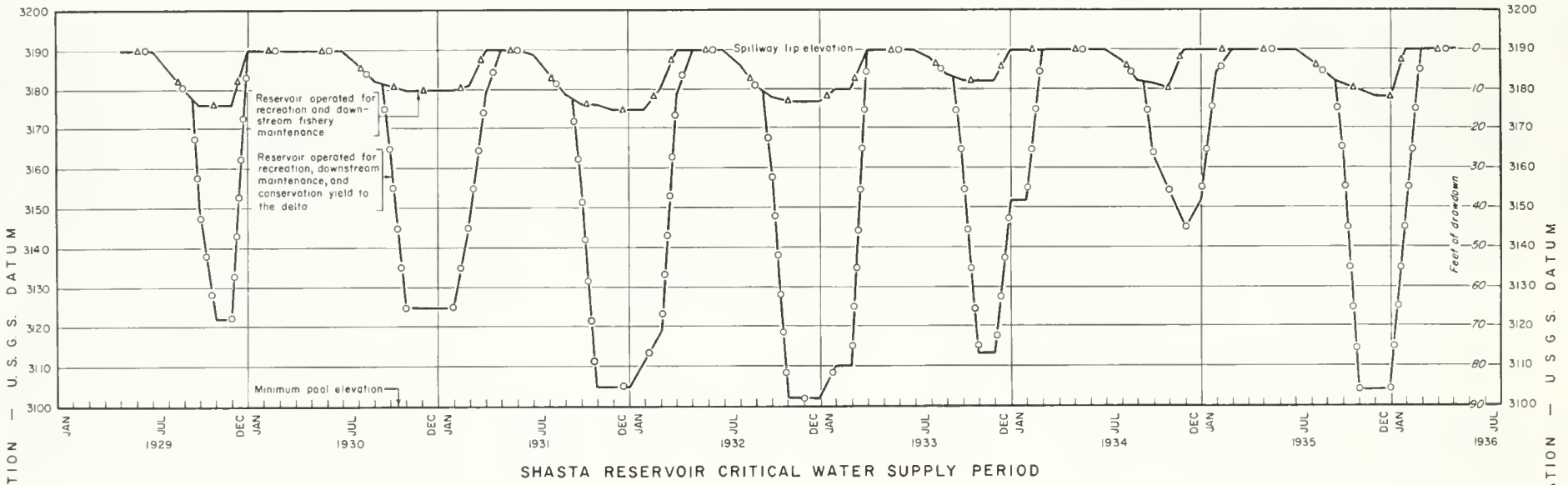
Project Operation

The operation schedule which would most benefit recreation at Box Canyon Reservoir would maintain a relatively constant pool elevation during the entire recreation season. A constant pool elevation during the entire year would also be beneficial to the reservoir fishery because of the additional production of fish food in shallow areas. However, the releases recommended by the Department of Fish and Game to maintain certain flows in the downstream fishery would cause some drawdown of the reservoir pool during dry seasons of most years. More severe drawdown would occur as the result of releases of stored water to fulfill the water conservation purpose to supply new yield to the State Water Facilities. Although these two requirements for project water--maintenance of constant pool in the reservoir and releases for either maintenance of flow in the downstream fishery or for water conservation--are somewhat incompatible, the reservoir could be operated satisfactorily to the mutual advantage of these purposes.

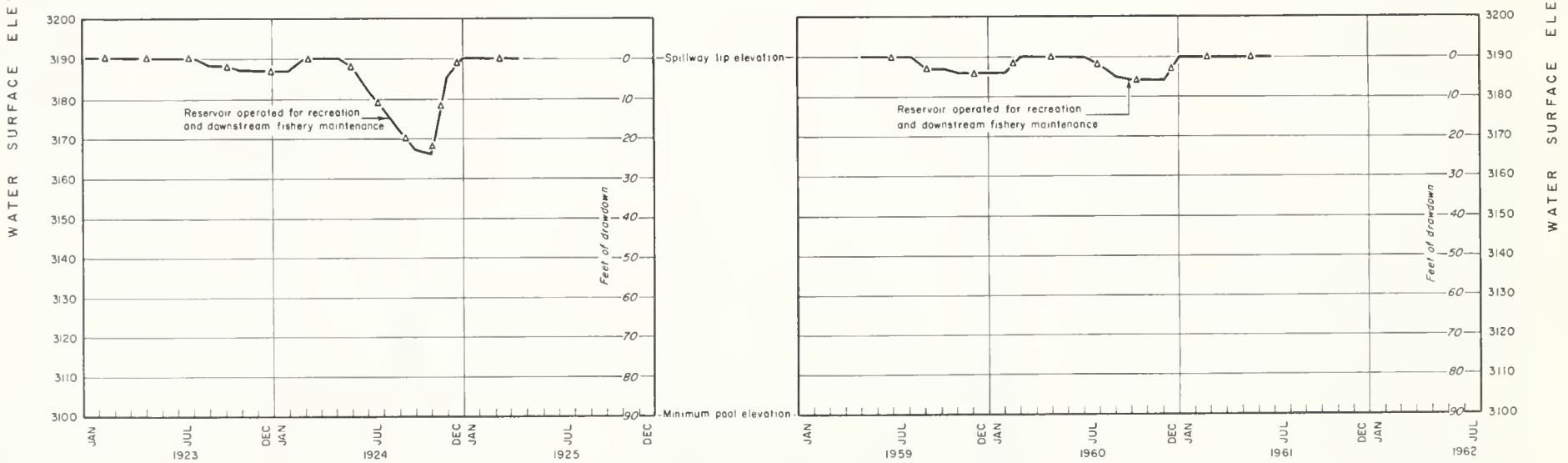
Single-Purpose Project Operation

Box Canyon Reservoir would fill each winter because of the large annual runoff which, on the average, is six times the storage capacity. In accordance with downstream fishery requirements, releases of at least 40 second-feet could be maintained during the summer months and yet the reservoir would fill each winter. The reservoir would normally spill during the winter, spring, and early summer, but in years of less than average water supply, the summer inflow would drop below the required release of 40 second-feet. During July, August, September, and October of some years, releases would be made from stored water to maintain the downstream fishery. These releases, as well as evaporation, would cause lowering of the reservoir.

Figure 6 shows approximate reservoir fluctuations which would have occurred during the two driest periods between 1910 and 1960 (1923-1925 and 1929-1936) with the reservoir being operated as outlined above. Graphs are also



SHASTA RESERVOIR CRITICAL WATER SUPPLY PERIOD



WORST WATER PRODUCING SEASON DURING 50 YEAR PERIOD, 1911-1960

NEAR AVERAGE WATER PRODUCING PERIOD

BOX CANYON RESERVOIR WATER SURFACE FLUCTUATION

FIGURE 6

presented of reservoir fluctuations for 1959-60, for which years records of streamflow are available. Figure 6 shows that the worst condition in the 50-year period would occur as a 24-foot drawdown in the fall of 1924. The next worst condition would be a 14-foot drawdown in the fall of 1931. Extreme lowering, such as in these two years, would occur infrequently. In 1923, only 3 feet of drawdown would occur; and in 1959, only 4 feet of drawdown would result. Between the extremes of maximum and minimum drawdown, it is estimated that the reservoir would fluctuate between zero and 6 feet about half the time during near-normal years and between zero and 12 feet during drier years.

Multipurpose Project Operation

Box Canyon Reservoir, operated as a multipurpose recreation and conservation project, would be managed as described for a single-purpose project except during a critical period when the release would be required for downstream water demands. The release of water from Box Canyon Reservoir would be made to augment downstream water projects to provide an additional increment of water to the State Water Facilities. Water stored in Box Canyon Reservoir would be released for this purpose only in a critical dry period.

Operation studies of projects contributing to the Delta water supply were predicated upon a critical period that would probably occur once in 50 years with water supply conditions such as prevailed from 1928-29 through 1934-35. As indicated by these studies, surplus waters stored in Box Canyon Reservoir would be released in a year corresponding to 1929, during which year storage in Shasta Reservoir would have dropped to a low of about 1,100,000 acre-feet. Box Canyon Reservoir would release its entire available storage during a six-week period in the fall after the recreation season. This water would be conveyed to the Delta for further diversion.

Box Canyon Reservoir would fill and spill during the winter and would be operated for recreation during the following summer. However, the water

stored during the critical period would be released in the fall to replace water that otherwise would be stored in Shasta Reservoir. The fall release of water from Box Canyon Reservoir would continue each year until Shasta Reservoir would spill and new surplus water could be stored in Box Canyon Reservoir. Figure 6 shows approximate reservoir fluctuations which would occur during the critical period if the reservoir were operated to augment downstream water supplies.

The operation described above would permit Box Canyon Reservoir to maintain its normal, high-level recreation pool during the summer months, but would have an adverse effect on the reservoir trout fishery by the seasonal release of water for seven years. No doubt, many fish would be lost during the release of water, but more serious would be loss of the reservoir's food-production characteristics by the extreme fluctuation and interference with the spawning and rearing of young fish. It has been assumed that this situation could be satisfactorily corrected by planting catchable-sized fish during and after the critical period operation. The cost of the fish planting program would be assessed against the conservation purpose.

Project Accomplishments

The development of a recreation-oriented reservoir project at Box Canyon would add to the supply of water-associated recreation facilities required to keep pace with the increasing demand for facilities of this type in California. The project would provide a variety of recreation opportunities both to day-users from the Mt. Shasta City-Dunsmuir area and to campers and sightseers from all parts of the State. These recreationists would come to enjoy the fishing, boating, swimming, camping, picnicking, and sightseeing in the attractive setting that Box Canyon Reservoir would create. The operation of Box Canyon Reservoir as a multipurpose project to release water during a critical period would add new yield to the State Water Facilities.

The primary accomplishment of the Box Canyon Project, either single-purpose or multipurpose, would be to provide a 485-acre water surface with a shoreline and surrounding area suitable for recreation development. With Box Canyon Reservoir operated for recreation and fishery enhancement, the maximum reservoir drawdown during the recreation season in most years would be less than 6 feet below the normal pool elevation. A stable water surface elevation in the Box Canyon Reservoir would create a productive reservoir trout fishery.

Primary Recreation Benefits

Primary recreation benefits of the Box Canyon Project were estimated in the manner described in Chapter III and are the same as those developed in that chapter to determine the justification of recreation as a separable purpose in a multipurpose project. Total primary recreation benefits at the proposed Box Canyon Reservoir therefore are estimated to be $9,470,000 when expressed as the present worth value of annual benefits over a 50-year repayment period.

Secondary and Intangible Recreation Benefits

Economic justification of the Box Canyon Project can be based only on its primary recreation benefits, not on such secondary benefits as increased property values, new capital induced into the community and increased local net income. Furthermore, intangible esthetic and social benefits that would be created by construction of the Box Canyon Project do not lend themselves to measurement in monetary terms. Although secondary and intangible benefits do not receive consideration in project formulation, they are a factor to consider in establishing the need for the project.

A study of the economic value of state parks in Oregon, for instance, revealed that park visitors stay longer in a general area because of the presence of a park. In the southern Siskiyou and northern Shasta County areas

surrounding Box Canyon Reservoir, such an increased length of stay would mean greater expenditures by the recreationists. The needs of recreationists for goods and services in this general area would increase the sales at present business establishments, create the need for new businesses, and stimulate the investment of new capital in the community. The resulting increased value of private property in the vicinity of Box Canyon would create an assessed valuation greater than that which exists under conditions without a project.

As for intangible benefits, these have been stressed by recreation and park planners who have visited the project area and praised the high esthetic quality of the setting.

Fishery Maintenance and Enhancement

As previously stated, estimated primary recreation benefits include the benefits resulting from an improved trout fishery. The following paragraphs discuss the fishery aspects of a single-purpose recreation Box Canyon Project.

Working with the Department of Water Resources, the Department of Fish and Game investigated possible effects of the proposed Box Canyon Project on fish and wildlife and presented its conclusions in a report entitled "Interim Report on the Probable Effects of Box Canyon Reservoir on Fish and Wildlife Resources of the Upper Sacramento River," August 1962. This study showed that the existence of a recreation reservoir at Box Canyon would result in increased natural production of trout in that portion of the Sacramento River and its tributaries in the vicinity of the reservoir. It also showed that, at no additional management expense, the expected increase probably would provide the angler with many more fish in the reservoir.

Reservoir Fishery. The streams within the reservoir area presently contain resident populations of rainbow and brown trout. Blockage by Shasta Dam has eliminated the migrations of anadromous fishes which at one time

utilized this area. The Department of Fish and Game plants catchable-sized rainbow trout in streams within the project area. However, approximately 18 times as many fingerlings could be planted annually in Box Canyon Reservoir for the annual amount of money expended in recent years for planting catchables. Fingerlings experience a higher mortality rate than catchables, particularly when planted in streams, but estimates indicate that the yield of hatchery-reared fingerling trout from Box Canyon Reservoir would at least triple the present yield of the streams that would be inundated.

The natural saucer-like shape of the bottom of the reservoir would provide large areas of water less than 30 feet deep. These areas would be natural fish food-producing areas and, coupled with spawning gravels in the tributaries to the reservoir, would produce a reservoir highly suited to natural trout production. Operation of the reservoir as a stable pool would further enhance natural trout production because such operation would preserve all food-producing areas.

Increased natural production of trout added to the expected increase in yield of hatchery-reared fingerling trout in the reservoir would more than quadruple the present yield from the inundated area at no additional expense.

Downstream Fishery. As a result of its study, the Department of Fish and Game made the following recommendations for maintenance of the fishery downstream from the reservoir:

> "When the reservoir is filling, the following tentative releases, or the actual flow, whichever is less, should be made:
>
> | | |
> |---|---|
> | January and February: | 150 second-feet |
> | March, April, and May: | 100 second-feet |
> | June and July: | 75 second-feet |
> | August and September: | 50 second-feet |
> | October: | 75 second-feet |
> | November and December: | 100 second-feet |

- After the reservoir fills, a fishery maintenance flow consisting of the actual inflow to the reservoir, minus evaporation, should be released below the proposed dam, except that the release should never be less than 40 second-feet.

- The reservoir pool should not be drawn below elevation 3,180 feet (10 feet below normal pool) without prior approval of the Department of Fish and Game. This restriction might necessitate a compromise between the maintenance of a downstream release and the reservoir stage during an extremely dry year.

- Provisions for a high-level and a low-level outlet should be included in the dam design. Each outlet should have a capacity of at least 50 second-feet. The high-level outlet should be provided with a suitable screen to prohibit fish from leaving the reservoir.*

- Plans for installing a thermograph at the Department of Water Resources' gaging station below Box Canyon (Sacramento River near Mt. Shasta) should be put into effect at the earliest possible date. Water temperature data should be collected from the time of installation until five years after project completion to aid in determining the proper temperature of the release.

Regulation of summer flows and control of water temperatures downstream from the dam may improve the present fishery, but, with data available during this investigation, prediction of specific enhancement was not possible.

Water Conservation Benefits

Box Canyon Reservoir would store 30,000 acre-feet of water at the normal pool elevation of 3,190 feet, USGS datum. Of the total storage capacity, 5,000 acre-feet would be reserved as inactive storage for preservation of fishlife, an additional 5,000 acre-feet would be carried over and released as needed to replace increased evaporation caused by summer holdover in Box Canyon Reservoir. The remainder of 20,000 acre-feet would be available for release for downstream needs. To compute the benefits accruing to Box Canyon Reservoir for the development of new yield, it was assumed that the entire release of 20,000 acre-feet would be transported to the Sacramento-San Joaquin Delta and from there be diverted by

*The design of the proposed Box Canyon Dam and Reservoir has incorporated the suggestions in this item.

the State Water Facilities. The release and diversion of 20,000 acre-feet during one low-supply year of the critical dry period would be equivalent of a firm annual yield of 2,900 acre-feet. In effect, the provision of 25,000 acre-feet of active storage at Box Canyon Reservoir would allow the entire system contributing to the Delta diversion to be operated each year to produce an additional 2,900 acre-feet.

The benefits would begin accruing to Box Canyon Reservoir in 1982, when estimated increased water demands would exceed the initial capacity of the State Water Facilities. Benefits accruing to the Box Canyon Project over the remaining 38 years of the repayment period, but reduced to present worth in 1970, were estimated to be $1,423,000. A unit annual benefit of $40 per acre-foot is currently (1962) being used in evaluation studies of the State Water Facilities and is applicable to analyses of future projects which may develop water supplies for export from the Delta Pool.

Engineering Feasibility and Economic Justification

Investigation results indicate that the Box Canyon Project as formulated possesses engineering feasibility and meets those requirements of engineering feasibility presented at the start of this chapter:

- The water supply is adequate in quantity and quality for the proposed size of the project.
- The dam and reservoir sites are geologically suitable for the proposed structures and their uses (provided that geologic problems receive proper consideration during final design and construction).
- Design and construction possibilities are such that the proposed uses of the project will be served efficiently and safely.
- Construction is possible with available materials and present techniques at reasonable cost.

Single-Purpose Project

For the Box Canyon Project, formulated as a single-purpose recreation project, to be economically justified, its recreation benefits must exceed the entire cost of the project.

The present worth value of recreation benefits throughout a 50-year repayment period (1970 to 2020) was estimated to be $9,470,000. The total capital cost of the project, based on 1961 price levels and including the present worth value of future expenditures for additions, operation, and maintenance, was estimated to be $8,403,000. The resulting benefit-cost ratio, 1.13 to 1, indicates economic justification.

As previously noted, secondary benefits were not included in project benefits. However, consideration of secondary benefits resulting from increased income to the Mt. Shasta City-Dunsmuir area would increase the degree of economic justification.

Multipurpose Project

With the Box Canyon Project designed and operated as a multipurpose project for recreation and water conservation, the project benefits, cited above, would be reduced by $35,000 due to loss of recreation benefits from fishing use, but would be increased by $1,423,000 due to water conservation benefits. The resulting project benefits throughout the 50-year repayment period were estimated to be $10,858,000. The total capital cost of the multipurpose project, including the items cited above for the single-purpose project and with the higher cost of the outlet works, was estimated to be $8,724,000. The resulting benefit-cost ratio of 1.24 to 1 indicates economic justification.

Cost Allocation

An estimate was made of the proportions of the cost of the multipurpose project that could be allocated to the recreation and water conservation purposes in accordance with the separable costs-remaining benefits method. For each of the purposes, the benefits set forth above would be limited by the least costly alternative. The benefits accruing to recreation under the multipurpose project would be limited to the cost of the single-purpose recreation project

($8,403,000), The conservation benefits would be limited to $356,000 under the assumption that new yield could be added to the Delta at a cost of approximately $10 per acre-foot from alternative sources. The separable costs of the recreation and conservation purposes were computed to be $4,107,000 and $321,000, respectively. It was found that approximately 99 percent of the remaining benefits would accrue to recreation and 1 percent would accrue to conservation. On this basis, the total project costs would be allocated in the amounts of $8,368,000 to recreation and $356,000 to conservation. Thus, it may be seen that even with the addition of the water conservation purpose to the Box Canyon Project, nearly all the costs (96 percent) would be attributed to recreation.

Project Selection

In Chapter III, an analysis was made of the possible project purposes that could be included in a reservoir development project at the Box Canyon site on the Upper Sacramento River. The possible purposes investigated were recreation, flood control, hydroelectric power, irrigation, municipal and industrial uses, and new water yield to the Sacramento-San Joaquin Delta. It was found that only the purposes of recreation and new yield to the Delta would create benefits equal to or larger than their separable costs.

In the preceding sections of this chapter, it was shown that a reservoir development at the Box Canyon site could be formulated either as a single-purpose recreation project, or as a multipurpose recreation and water conservation project. Either project would be economically justified. However, it was indicated that there is a significant degree of uncertainty regarding the benefits that may accrue to the new Delta yield purpose. One such item is the small amount of water involved in the Box Canyon

Project in comparison to the Central Valley Project and the State Water Facilities. Another, and probably the most serious item, is the amount of the estimated benefit assuming that water from Box Canyon Project would be added to the State Water Facilities in 1982. If the Box Canyon Project yield were not added until some years later, the benefit would probably be less than the estimated separable cost. Also, operation of the water conservation purpose as described in this chapter would be incompatible in some degree with operation of the Box Canyon Reservoir for recreation and fishery enhancement.

It was, therefore, concluded that the Box Canyon Dam and Reservoir Project should be formulated and given further consideration as a single-purpose reservoir recreation project. As previously mentioned, no alternative water development project has been proposed that would fulfill the estimated recreation demand to the extent described for the Box Canyon Project.

State Park System Development

The Division of Beaches and Parks of the Department of Parks and Recreation has prepared a report entitled "Mt. Shasta-Siskiyou Area Study--An Analysis of State Park Potentials in Western Siskiyou County," dated January 2, 1962, in response to Senate Concurrent Resolution No. 46 and Assembly Concurrent Resolution No. 87 of the 1961 legislative session. This investigation and analysis identified five possible park and recreation projects, including the Box Canyon Project, that would be desirable additions to the State Park System. The above report recommended these be adopted as official projects of the State Park Program and that additional detailed planning and studies be performed.

The Division of Beaches and Parks considered establishment of park facilities in the Box Canyon area both with and without a reservoir as proposed by the Department of Water Resources. Both developments were

found to be desirable, and the Division of Beaches and Parks estimated that recreation use with the reservoir would be nearly double that without a reservoir.

During the 1962 calendar year, the Division of Beaches and Parks gave more detailed study to plans for a State Park System development in conjunction with the Box Canyon Reservoir recreation project as proposed in this Bulletin No. 100. This work was coordinated with the studies of the Department of Water Resources and resulted in substantial agreement in all phases of the planning. However, to establish a State Park System development at Box Canyon, the Division of Beaches and Parks would desire acquisition of lands in addition to those described in this bulletin as the reservoir recreation project area.

State Park System Lands

Cost estimates of the Box Canyon Single-Purpose Recreation Project as previously presented were predicated upon acquisition of 2,088 acres considered as the minimum reservoir recreation project area to provide for the dam and reservoir, and for lands for recreation facilities to meet the estimated water-associated recreation demands. Standards of the Department of Parks and Recreation for establishment of a State Park System development at Box Canyon would require acquisition and management of lands in addition to those delineated for the reservoir recreation project area to provide for uses other than water-associated recreation.

Acquisition of an additional 2,330 acres on the south and west of the reservoir project boundary would provide complete public access to adjoining lands of the U. S. Forest Service, Shasta National Forest. The Department of Parks and Recreation foresees many recreation benefits forthcoming from the opportunity for visitors at the Box Canyon Project to visit and make use of the Castle Lake-Gumboot Lake area. Their January 1962 report states, "Working on a cooperative basis with the Forest Service, we would help bring about realization of the total recreational potential of this beautiful area."

Management of the recreation area would be enhanced by acquisition of 430 acres to the north of the reservoir recreation project boundary to include lands within the immediate watershed along Rainbow Ridge to the north. One of the purposes of these additional lands would be to preserve the scenic character of the lands surrounding the proposed park area. Another would be to protect and preserve the quality of runoff from the immediate watershed which may otherwise be subject to degradation from residential or commercial development.

The addition of these lands to the reservoir recreation area would increase the project area for a desirable State Park System development to about 4,800 acres. It is estimated, without actually appraising the additional lands, that the increased cost to the project would be about $350,000.

Need and Implementation

The Mt. Shasta City-Dunsmuir Area Investigation was initiated in response to the need expressed by residents of the area for development of their local water resources. Throughout the period of the investigation, there was continual awareness by local residents and particularly the Siskiyou County Board of Supervisors in the engineering studies and results as presented herein. It was not foreseen that the most desirable water resources development at the Box Canyon site would be a single-purpose recreation project. Rather, it was expected that the various multipurpose uses analyzed in Chapter III would prove justifiable and would contribute to the financial feasibility of the project. Nevertheless, there is strong local support for construction of Box Canyon Dam and Reservoir as a single-purpose water project, because such construction and operation would be a valuable addition to the local economy, much of which is based on recreation. Increased recreation activity is viewed as a means to replace incomes lost to Siskiyou County by declines in lumbering, mining, and steam railroad equipment maintenance.

No formal investigation was made of the ability of a local agency in Siskiyou County to finance and construct a recreation reservoir project at Box Canyon. However, this appears unreasonable because only a part of the benefits would accrue to the local area. Most of the primary recreation benefits as computed herein and presented as the basis of economic justification would accrue to the recreation users and visitors who reside in other parts of the State. Therefore, it is considered that implementation of the Box Canyon Project would be dependent upon state financing, construction, and operation as a unit of the State Park System.

Advance Planning Program

In the event of legislative authorization for construction of the Box Canyon Project, an advance planning program would be required to establish the final criteria needed to prepare construction plans and specifications. The advance planning program would include additional geologic studies and drilling of the damsite, final sizing of the structures, detailed layout of on-shore recreation facilities, and other state park facilities. Programs would be established for operation and maintenance of the reservoir, the state park and recreation facilities, and for fish and game management for the purposes of designs of facilities. Arrangements would be made for relocation of roads, utilities, and related items that would affect establishment of final design criteria.

Emphasis would be given to further geologic exploration of the Box Canyon damsite to resolve questions concerning foundation conditions and possible seepage through the left abutment. It is proposed that five to seven diamond-drill core holes, totaling about 1,200 feet, be drilled to determine the physical nature, thickness, and grouting requirements of the

volcanic rock beneath the channel. Cable tool drilling is proposed on the higher portions of the abutments to determine the subsurface nature, thickness, and permeability of glacial and lake sediments. Further mapping, sampling, and testing would be done to locate and evaluate construction materials for the earthfill dam.

It is estimated that the advance planning program would be carried out through one fiscal year at a cost to the Department of Water Resources of $115,000. The program would be completed in the subsequent fiscal year at an additional cost of $7,000 for technical staff review, editing, and publication. The results of the program would provide data and criteria needed to prepare construction plans and specifications. The cost of final plans and specifications is included in the estimated cost of construction of the project.

CHAPTER V. CONCLUSIONS AND RECOMMENDATIONS

In the Mt. Shasta City-Dunsmuir area, located at the headwaters of the Sacramento River, where in the past agriculture, lumbering, and the railroad have provided its economic livelihood, recreation is rapidly becoming a new major industry. Local residents foresee development of the local water resources as another step toward development of a year-round vacation land.

Determination of the engineering feasibility and economic justification of a multipurpose dam and reservoir at Box Canyon on the Sacramento River about 2 miles southwest of Mt. Shasta City was requested by local interests, and subsequently was made the objective of this investigation. The following conclusions and recommendations are based upon analysis of data collected and developed for this investigation during field and office studies.

Conclusions

1. The Mt. Shasta City-Dunsmuir area possesses a scenic environment and climate ideally suited for both summer and winter recreation. The area, served by major transportation routes, is visited by increasing numbers of recreationists.

2. The portion of the Sacramento River Basin above Box Canyon damsite produces an abundant water supply. The 122 square mile drainage basin has an estimated average annual impaired runoff of 192,000 acre-feet.

3. The porous lower slopes of Mt. Shasta contain ground water which supplies hundreds of continuously flowing springs. These springs sustain flows in the Sacramento River and its tributaries during the summer months when little or no rainfall occurs.

4. The combination of good water supply and evident dam and reservoir sites at Box Canyon has long suggested that water storage facilities here would be of value to the Mt. Shasta City-Dunsmuir area. Investigation of the separable purposes envisioned for a multipurpose reservoir at Box Canyon resulted in the following conclusions:

a. Flood Control. In its present state, the Sacramento River poses a flood threat to the Dunsmuir-Castella area. However, the relative infrequency of damaging floods and comparatively small amount of damages that could be prevented by a reservoir at Box Canyon would not economically justify the inclusion of flood control measures in a reservoir project at Box Canyon.

b. Hydroelectric Power. Future demands for electric energy in this area could be supplied, in part, by hydroelectric generation at Box Canyon Reservoir. However, computation of benefits based on cost of energy from the most likely alternative source indicates that total annual benefits would be less than the annual cost of power facilities. Generation of hydroelectric power was not included in the final project.

c. Irrigation. The Wagon Creek Valley area would have no demand for irrigation water from a reservoir at Box Canyon because less expensive water could be developed from creeks, springs, and ground water sources. Although a large demand for water exists in Shasta Valley, the cost of transporting Sacramento River water to Shasta Valley would exceed the payment capacity of Shasta Valley water users. Therefore, use of project water for irrigation was not included in final project formulation.

d. Municipal and Industrial Uses. Study of present and future municipal and industrial water supplies within the project area showed that additional development of presently used and alternative supplies would be more economical than use of project water. Consequently, municipal

and industrial water development was not included as a purpose in the final project.

e. New Water Yield to Sacramento-San Joaquin Delta. Proper operation and release of water stored in Box Canyon Reservoir would provide new water yield to the Sacramento-San Joaquin Delta during a water-short critical period. The benefits derived from new yield would equal the cost of including the purpose in the project and of restoring the fishery which would be temporarily disrupted.

f. Recreation. The demand for recreation areas and facilities in the Mt. Shasta City-Dunsmuir area was found to exceed the supply. The benefits derived by including recreation as a purpose of a reservoir development at Box Canyon were shown to exceed the cost of the project.

5. Box Canyon Dam and Reservoir with a storage capacity of 30,000 acre-feet could be formulated either as a single-purpose recreation project, or as a multipurpose project for recreation and water conservation to supply new yield to the Delta.

6. Field and office investigation of the possible damsites at Box Canyon showed that the upper damsite located approximately 1,000 feet downstream from the Mt. Shasta City-Castle Lake road would serve most efficiently the recreation purpose of the project.

7. Geologic investigation revealed that the damsite would be suitable for a zoned earthfill dam with crest elevation of 3,215 feet. Further investigation of the damsite and further study of available construction materials would be necessary before construction designs could be completed.

8. The dam and reservoir to be included in the Box Canyon Project as described in Table 18 would comprise a 220-foot high earthfill dam at the upper site capable of storing 30,000 acre-feet of water at a normal pool (spillway lip)

elevation of 3,190 feet, USGS datum. The water surface area at the normal pool elevation would be 485 acres and at maximum water surface elevation would be 615 acres.

9. Camping provided by the project would be the major attraction, although day-use in the form of fishing, picnicking, swimming, and boating would attract many additional recreationists from the local area. Sightseeing also is expected to attract large numbers of recreationists.

10. In accordance with estimated demands for recreation use at the Box Canyon Project, it is estimated that initial recreation facilities installed to State Park System standards would include 245 camp units, 50 picnic units, sanitary facilities, water supply, access roads, beach improvement, boat launching ramps, overlook area for sightseers, parking lots, and concessions. Initial operation would provide for 125,000 visitor-days annually, estimated to occur in 1970.

11. The Box Canyon Project, with suitable recreation facilities, would satisfy an estimated demand of 125,000 visitor-days during the first year of operation and with properly expanded facilities would serve an estimated demand of 673,000 visitor-days at the end of 50 years. The present worth of total recreation benefits over the 50-year period would be $9,470,000.

12. The Box Canyon Project would enhance the fishery both within the reservoir area and downstream from the reservoir. Box Canyon Reservoir could be operated to maintain a nearly constant water surface during the entire year and still maintain adequate downstream flows for stream fishery enhancement. The reservoir, however, would inundate some intermediate deer range which would require replacement adjacent to the project area.

13. When operated for new yield to the Sacramento-San Joaquin Delta by releasing 20,000 acre-feet during one to two months of the critical period,

it would provide a new firm yield comparable to 2,900 acre-feet per year. A minimum pool of 5,000 acre-feet would be maintained in Box Canyon Reservoir. The reservoir would fill each winter following the conservation release but would have to return this water to Shasta Reservoir each fall until new surplus water that would otherwise spill from Shasta could be stored. The benefits creditable to this purpose were estimated to be $1,423,000.

14. The detriments to the fishery and recreation aspects of the project would be offset by planting fish each season during the critical period conservation operation. The additional costs of the fish planting program, expressed as the present worth of costs throughout the repayment period, would be $272,000. In addition, recreation benefits attributable to fishing would be reduced by $35,000 over the same period.

15. The Box Canyon Project demonstrates engineering feasibility because:

a. The water supply is adequate to meet the requirements of a reservoir used for recreation and downstream fishery enhancement.

b. The damsite is suitable for the dam proposed.

c. Natural materials for construction of the dam are available in sufficient quantity.

16. The costs of both the single-purpose and multipurpose recreation projects are shown in the following tabulation:

Item	Single-purpose recreation project	Multipurpose project
Initial expenditures	$4,788,000	$4,837,000
Future expenditures 1/	3,615,000	3,887,000
Total	$8,403,000	$8,724,000

1/ Includes present worth of future capital costs and annual outlay for operation, maintenance, and replacement.

17. A single-purpose recreation project at the Box Canyon site as described herein would create total benefits of $9,470,000 and would have a total project cost of $8,403,000 over the 50-year repayment period. The resulting benefit-cost ratio of 1.13 to 1 indicates economic justification.

18. A multipurpose recreation and conservation project at the Box Canyon site as described herein would create total benefits of $10,858,000 and would have a total project cost of $8,724,000 over the 50-year repayment period. The resulting benefit-cost ratio of 1.24 to 1 indicates economic justification.

19. An allocation of the multipurpose project costs to each purpose in accordance with the separable costs-remaining benefits method indicates that 96 percent of the costs would be creditable to recreation and 4 percent to conservation.

20. It is concluded that the most desirable project to be constructed at the Box Canyon site would be a single-purpose recreation and fishery enhancement reservoir project operated as part of the State Park System. This selection was made because of the small quantity of water to be developed by the conservation purpose, the uncertainty of the accrual of benefits, and the incompatibility of operation of the proposed reservoir for water conservation in conjunction with recreation and fishery enhancement purposes.

21. The State Division of Beaches and Parks has determined that the Box Canyon area possesses high potential for state park development without a reservoir, and an even higher potential for development should a reservoir be constructed at Box Canyon.

22. Development of a reservoir recreation project at Box Canyon would help satisfy growing statewide demands for outdoor recreation facilities and would augment economic conditions in southern Siskiyou County by increased recreation activity. Box Canyon Reservoir would provide trout fishery

enhancement. A state park system development would provide public access to an extensive area of National Forest lands in the Castle Lake-Gumboot Lake area.

23. No alternative project was found that would fulfill the needs described above to the extent demonstrated for the Box Canyon Project.

24. Implementation of the Box Canyon Project would be dependent upon state financing, construction, and operation as a unit of the State Park System.

Recommendations

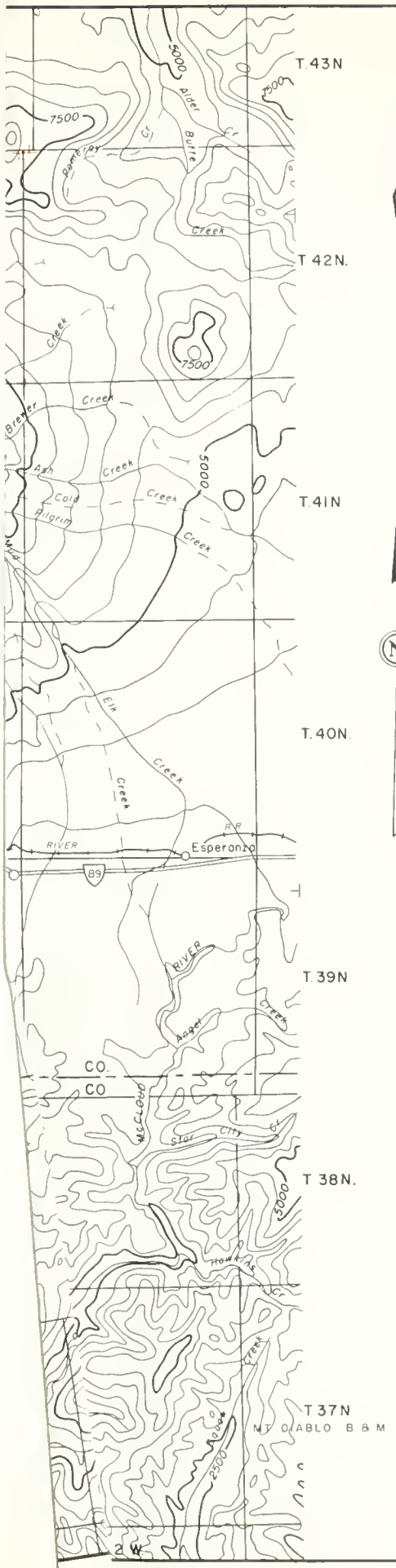
It is recommended that:

1. Box Canyon Dam and Reservoir Project set forth herein as a single-purpose reservoir recreation project be authorized and constructed as a unit of the State Park System and that the area of the unit be not less than the proposed recreation area shown on Plate 3.

2. The Department of Water Resources be authorized to proceed with acquisition of lands necessary for establishment of the reservoir recreation project, to complete advance planning to define criteria for final design, to prepare construction plans and specifications, and to take all steps necessary to construct the project, including recreation facilities, and to provide for future maintenance of Box Canyon Dam and Reservoir.

3. Additional funds in the amount of $115,000 be added to the Department of Water Resources 1963-64 budget to provide for advance planning and geologic investigation of the Box Canyon site.

4. The Department of Parks and Recreation give consideration to a program for acquisition of additional lands, outside the proposed recreation area cited above, to provide for state park purposes other than water-associated recreation; and further, upon approval of funds for advance planning, enter into a cooperative agreement with the Department of Water Resources to do detailed planning of recreation facilities at the proposed Box Canyon Reservoir.



LEGEND

- BOUNDARY OF SACRAMENTO RIVER BASIN
- BOUNDARY OF DRAINAGE AREA ABOVE BOX CANYON DAM SITE
- IRRIGABLE LANDS
- FLOOD DAMAGE AREA
- BOUNDARY OF MT SHASTA CITY-DUNSMUIR AREA

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

MT. SHASTA CITY-DUNSMUIR AREA INVESTIGATION

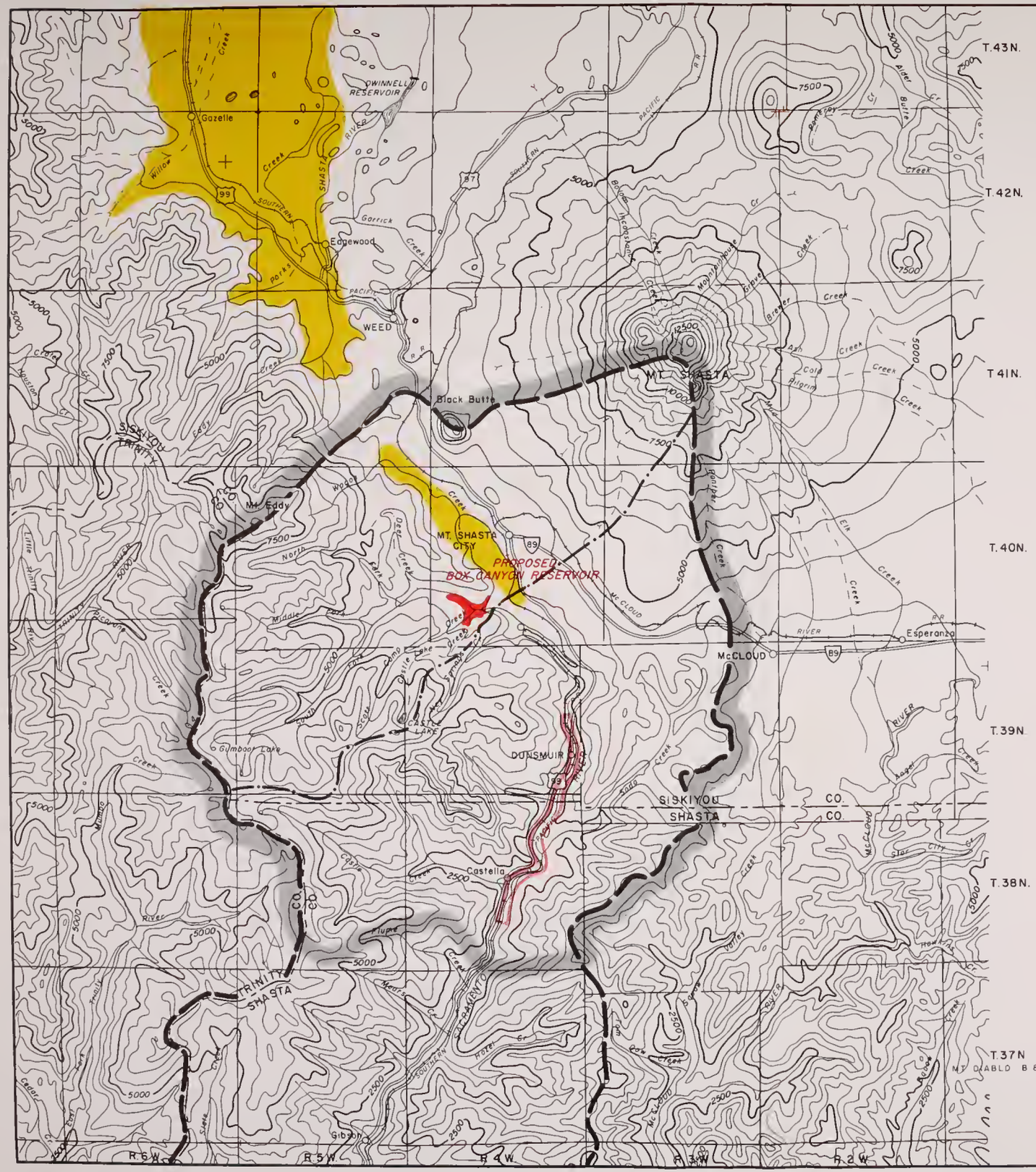
PROJECT AREA

1962

SCALE OF MILES

2 0 2 4 6

Contour Interval 500 Feet - U.S.G.S. Datum



LEGEND

- BOUNDARY OF SACRAMENTO RIVER BASIN
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MT. SHASTA CITY-DUNSMUIR AREA INVESTIGATION

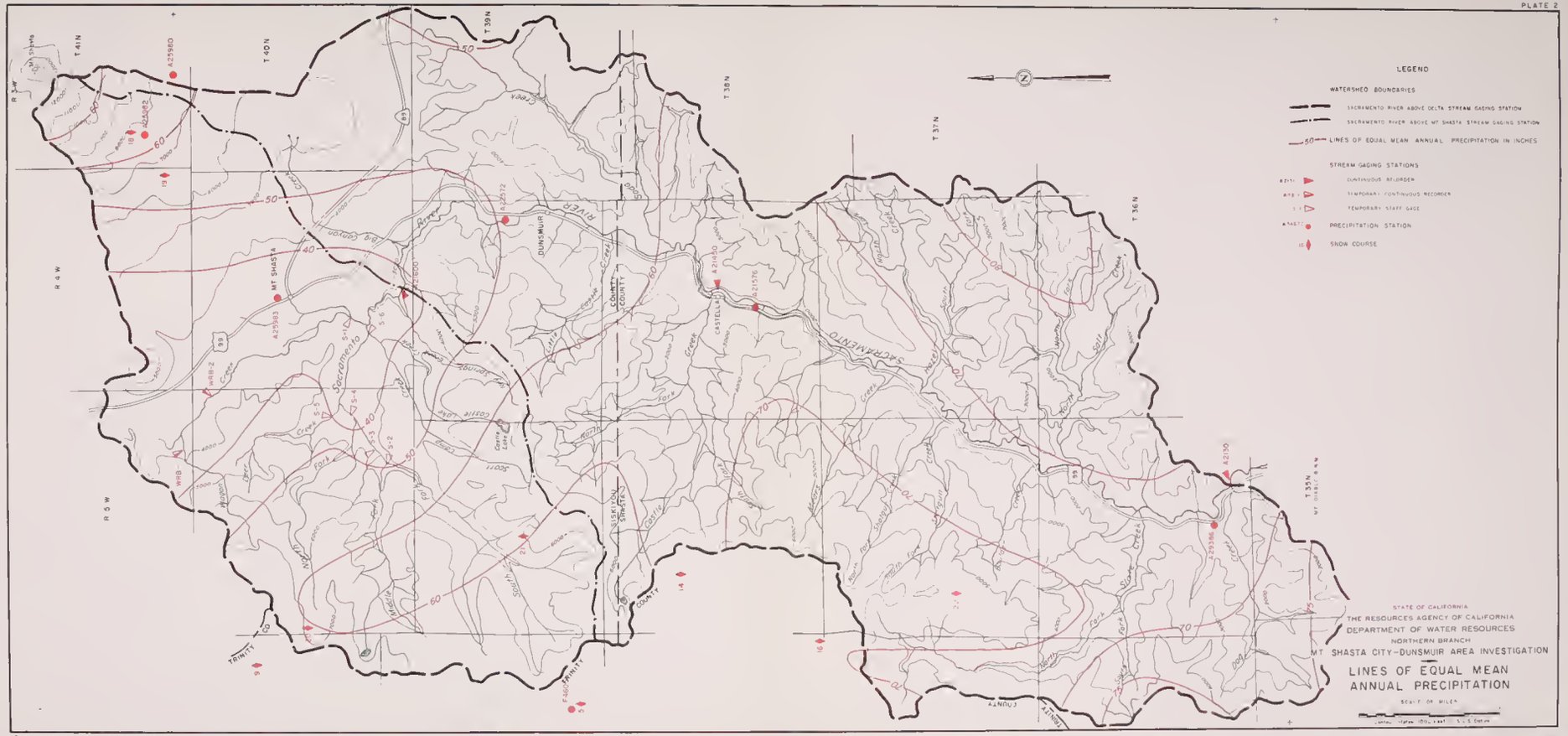
PROJECT AREA
1962

SCALE OF MILES
2 0 2 4 6

Contour Interval 500 Feet - U.S.G.S. Datum

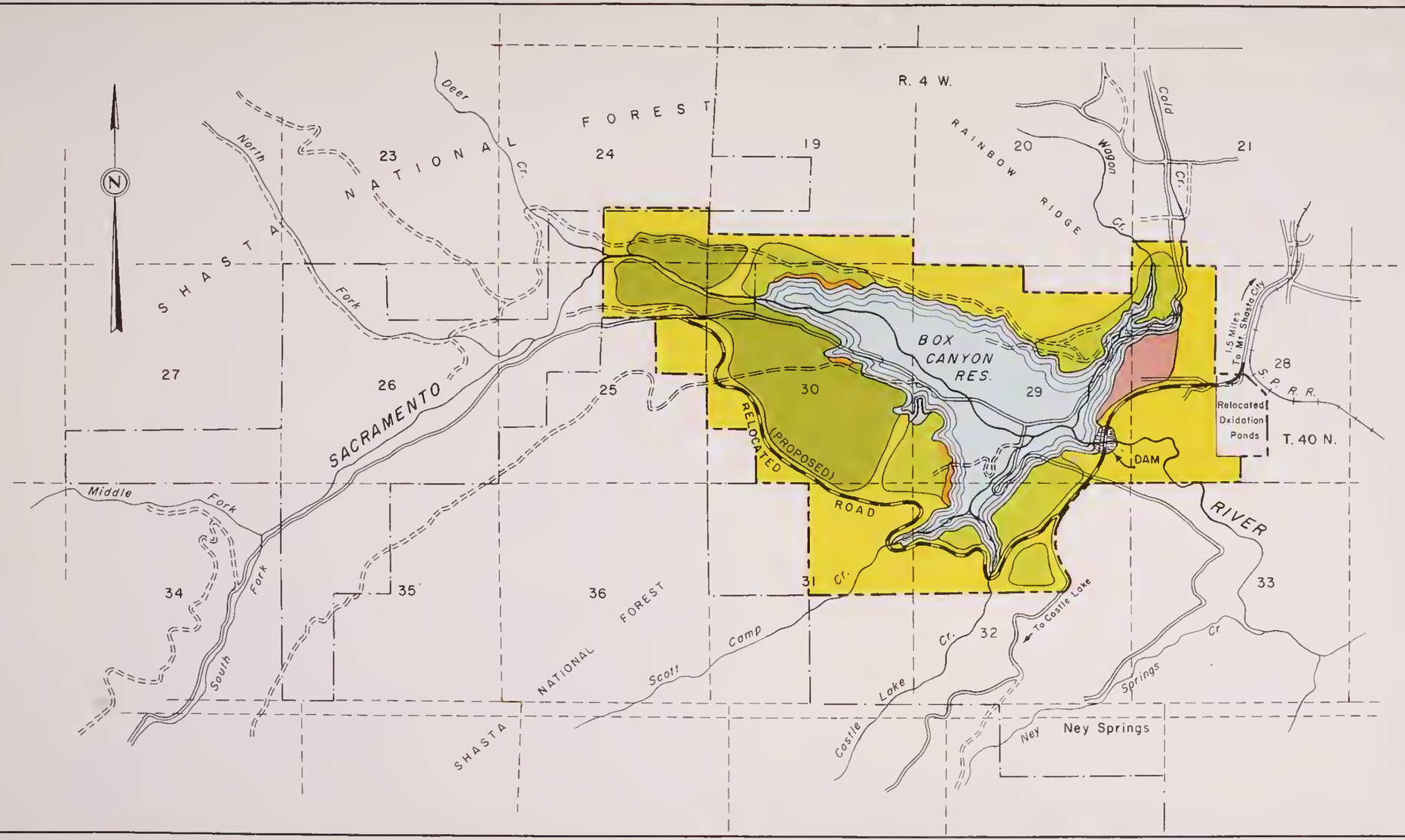
Identification Number	Name	Operator *	Period of Record	Estimated Average Annual Precipitation (in inches) 1905 1955	Estimated Average April 1 Water Content (in inches) 1930 1959
Precipitation Stations					
A25980	Mt Shasta Ski Bowl	USWB	1958 date	—	
A25982	Mt Shasta Slope	USWB	1927 date	61 9	
A25983	Mt Shasta City	USWB	1888 date	33 5	
A25572	Dunsmuir Ranger Station	USWB	1889 date	51 2	
A21576	Castella	Private	1953 date	62 5	
A29386	Vollmers	USWB	1927 date	62 7	
F66072	Mumbo Basin	USWB	1946 date	49 8	
Snow Courses					
9	Deadfall Lakes	DWR	1946 date		33
14	Whaleback	DWR	1940 date		20
15	Mumbo Basin	DWR	1947 date		26
16	Highland Lakes	DWR	1947 date		22
18	Mount Shasta	DWR	1930 date		49
19	Sand Flat	DWR	1945 date		41
20	North Fork Sacramento	DWR	1956 date		23
21	Grey Rock Lakes	DWR	1961 date		64
22	Slate Creek	DWR	1945 date		28
Stream Gaging Stations					
A21300	Sacramento River at Delta	USGS	1945 date		
A21450	Sacramento River at Castella	USGS	1911-23		
A21600	Sacramento River near Mt Shasta	DWR	1959 date		
WRB 1	Mogan Creek at Mills Ranch	WRB	May Dec 1960		
WRB 2	Mogan Creek below Mills Ranch	WRB	May Dec 1960		
S 1	Mogan Creek below Cold Creek	DWR	July-Dec 1960		
S 2	South Fork Sacramento River at Bridge	DWR	July Dec 1960		
S 3	Sacramento River between Middle Fork & North Fork	DWR	July-Dec 1960		
S 4	Sacramento River between North Fork & Deer Creek	DWR	July-Dec 1960		
S 5	Deer Creek at Bridge	DWR	July Dec 1960		
S 6	Scott Camp Creek at Bridge	DWR	July-Dec 1960		

* USWB United States Weather Bureau
DWR Department of Water Resources
USGS United States Geological Survey
WRB Water Rights Board



DEPARTMENT OF WATER RESOURCES 1962

PLATE 3



LEGEND

- BEACH AREA
- PICNIC AREA
- CAMPING AREA
- BOAT LAUNCH
- NATURAL AREA
- OVERLOOK AREA
- CONCESSION AREA

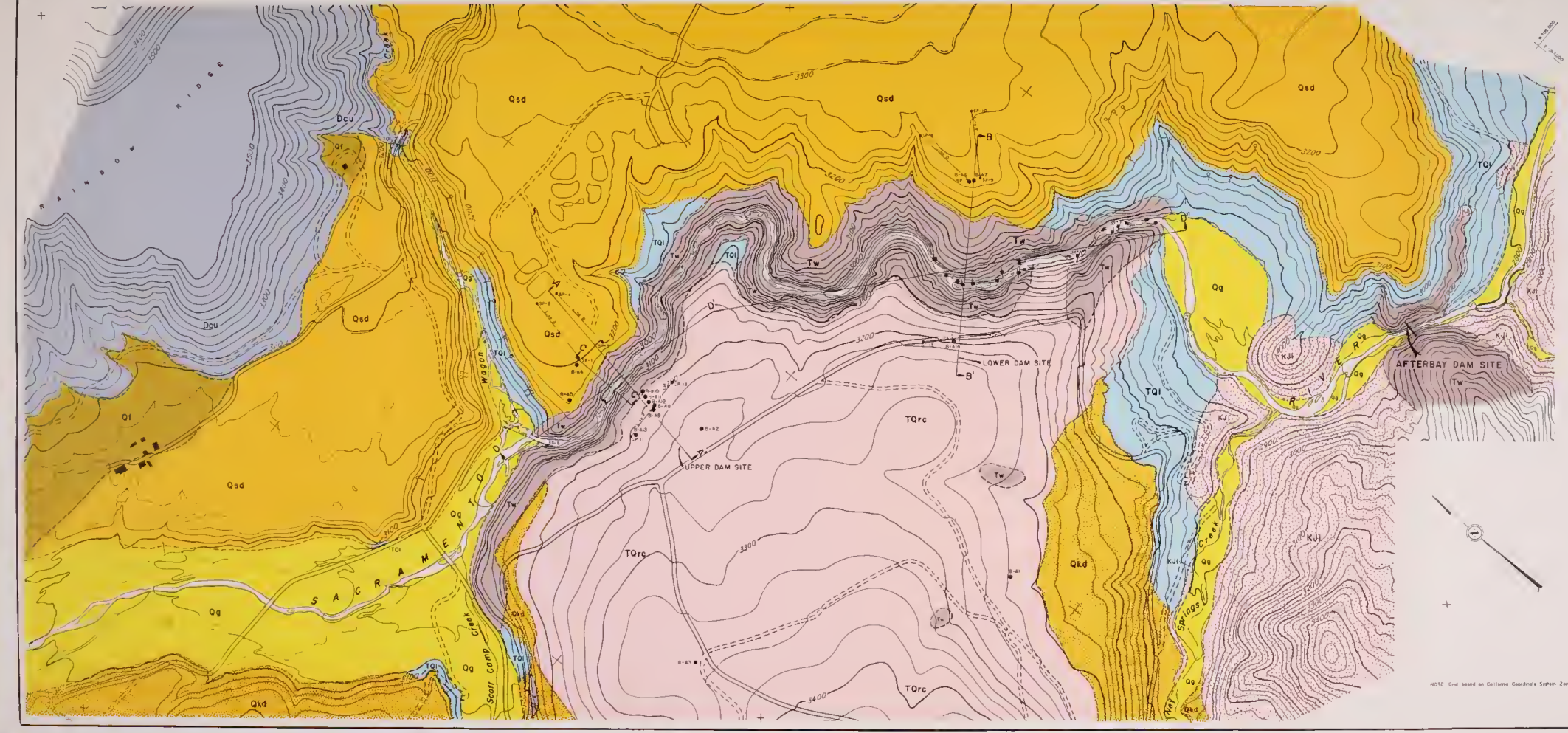
SHASTA NATIONAL FOREST BOUNDARY

PROPOSED RECREATION AREA BOUNDARY
Minimum reservoir recreation project area to provide for dam and reservoir, and recreation facilities to meet water-associated recreation demand.

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
MT. SHASTA CITY-DUNSMUIR AREA INVESTIGATION

BOX CANYON RESERVOIR RECREATION LAND USE PLAN
1962

SCALE OF MILES
0 1/2



NOTE: Grid based on California Coordinate System Zone I

LEGEND

QUATERNARY

- Qg — STREAM GRAVEL: BOULDERS, GRAVEL, SOME SAND, ROUNDED; COMPOSED OF MANY INTRUSIVE AND VOLCANIC ROCK TYPES
- Qf — ALLUVIAL FANS: POORLY SORTED ANGULAR DEBRIS FROM RAINBOW RIDGE
- Qkd — SHASTA GLACIAL DRIFT: GRAVELLY SANDY SILT COMPOSED OF ANGULAR FRAGMENTS OF VARIETIES OF ANDESITE DERIVED FROM MOUNT SHASTA AND ITS SUBSIDIARY CONES
- Qsd — KLAMATH GLACIAL DRIFT: ROUNDED GRAVEL IN A SILTY CLAY MATRIX; DERIVED FROM MESOZOIC INTRUSIVE ROCKS, WESTERN CASCADE VOLCANIC ROCKS AND PALEOZOIC ROCKS

TERTIARY

- TQl — LAKE DEPOSITS: SAND, SILT, CLAY, AND ASH; WELL BEDDED; SLIGHTLY CONSOLIDATED
- TQrc — RED CLAY: PLASTIC SILT AND CLAY; RESIDUAL SOIL AND COLLUVIUM MANTLING WESTERN CASCADE VOLCANICS
- Tw — WESTERN CASCADE VOLCANICS: DENSE FINE GRAINED ANDESITE FLOWS AND TUFFS

PRE TERTIARY

- KJl — INTRUSIVE COMPLEX: ALTERED INTERMEDIATE TO ULTRABASIC ROCKS OF PORPHYRITIC TO EQUIGRANULAR TEXTURES
- Dcu — COPLEY GREENSTONE: METAVOLCANIC ROCK

SYMBOLS

- B-45 ● — AUGER DRILL HOLE
- CONTACT APPROXIMATELY LOCATED
- CONTACT CONCEALED
- A — A' — GEOLOGIC SECTION
- VERTICAL JOINT
- INCLINED JOINT
- SPRING
- SHEAR ZONE
- SEISMIC LINE
- SHOT POINT

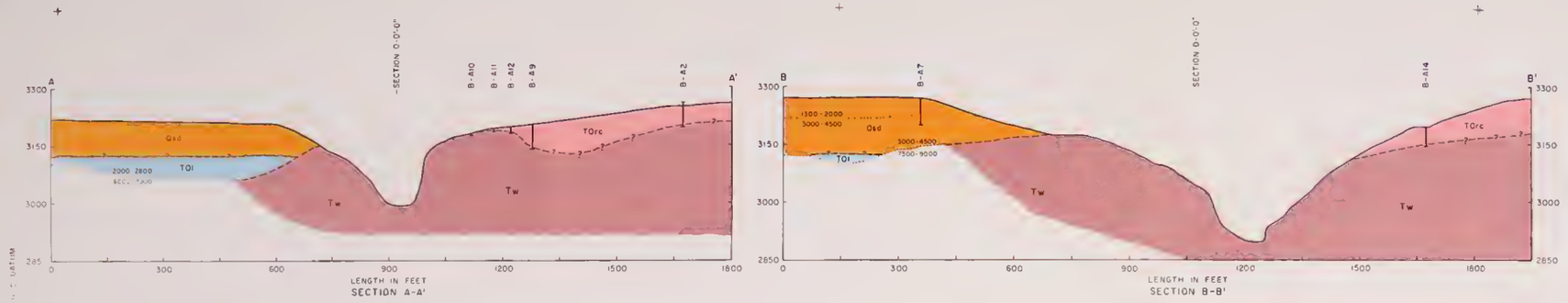
NOTES

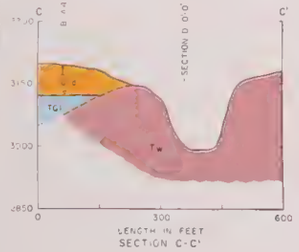
1. FOR LOCATION OF CONSTRUCTION MATERIALS REFER TO PLATE 8
2. FOR GEOLOGIC SECTIONS REFER TO PLATE 5
3. FOR LOGS OF AUGER HOLES REFER TO PLATE 5

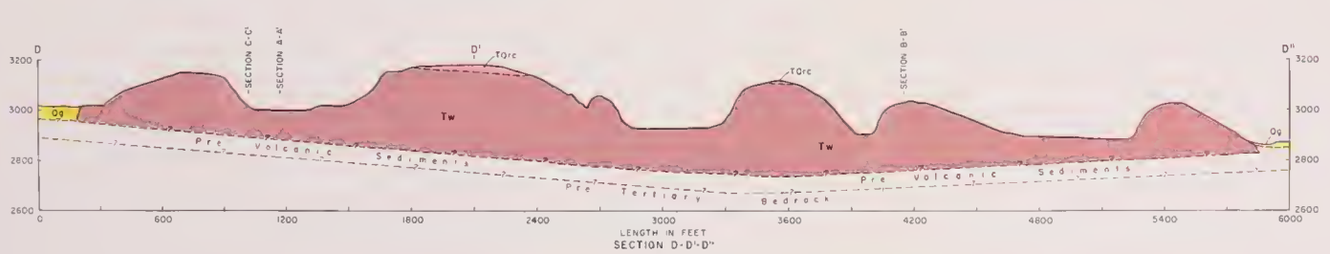
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
MT. SHASTA CITY-DUNSMUIR AREA INVESTIGATION

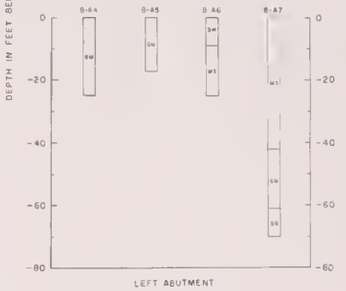
BOX CANYON DAM SITE
AREAL GEOLOGY
1961

SCALE OF FEET
500 0 300 600 900
Contour Interval 25 Feet - U.S.G.S. Datum









LEGEND

ORGANIC

GRAVEL, SAND, SILT, AND CLAY

SILTY SAND

SILT

GRAVEL, SAND, SILT AND CLAY

SAND, SILT

GRAVELLY SAND

COLLECTIVE REFUSAL

NOTES

CLASSIFICATIONS BASED ON LABORATORY TESTS COMBINED WITH FIELD DATA AND PERCENTAGES ARE ESTIMATED FROM FIELD DATA. SYMBOLS ARE UNIFIED CLASSIFICATION SYSTEM.

LEGEND

Qs — STREAM GRAVEL

Qsd — SHASTA GLACIAL DRIFT

TOl — LAKE DEPOSITS

TOrc — RED CLAY

Tw — WESTERN CASCADE VOLCANICS

SYMBOLS

— AUGER HOLE

— — — CONTACT BASED ON DRILLING OR SURFACE DATA

— · · — CONTACT BASED ON SEISMIC PROFILE NUMBERS INDICATE VELOCITY OF SHOCK WAVES IN FEET PER SECOND

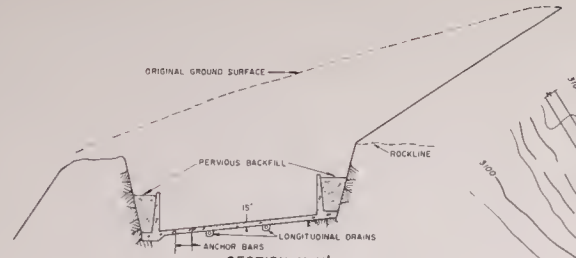
NOTE: FOR LOCATION OF SECTIONS AND EXPLANATION OF THE GEOLOGIC UNITS REFER TO PLATE 4

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
MT SHASTA CITY - DUNSMUIR AREA INVESTIGATION

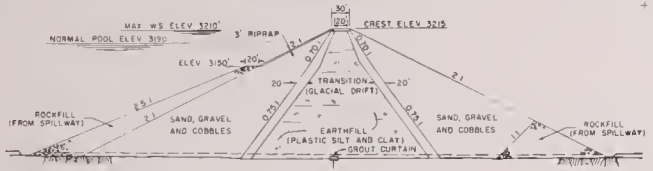
GEOLOGIC SECTIONS AND AUGER HOLE LOGS

1961

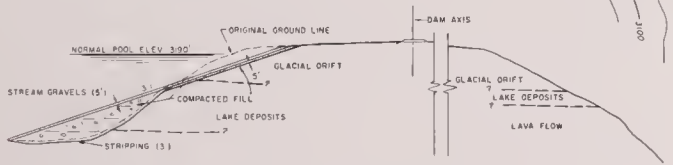

N 714,000
E 1,914,000
TO MT. SHASTA CITY
TO DUNSMUIR
B-3
B-1
B-3
B-1
B-1
SACRAMENTO
UPPER DAM SITE
LOWER DAM SITE
B-2
B-4
Q-4
Q-3
Q-1
Q-2
N 705,000
E 1,905,000
NOTE: Grid based on California Coordinate System Zone I
LEGEND
SAND AND GRAVEL
IMPERVIOUS
QUARRY ROCK
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
MT. SHASTA CITY-DUNSMUIR AREA INVESTIGATION
BOX CANYON DAM SITE
LOCATION OF CONSTRUCTION MATERIALS
SCALE OF FEET
1000 0 1000 2000



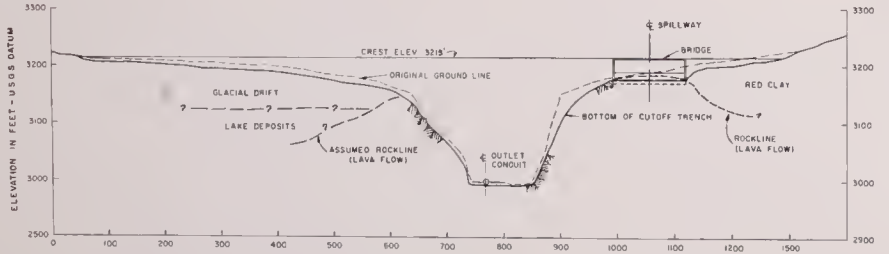
SECTION Y-Y'
TRANSVERSE SECTION THRU SPILLWAY
SCALE OF FEET
0 20 40



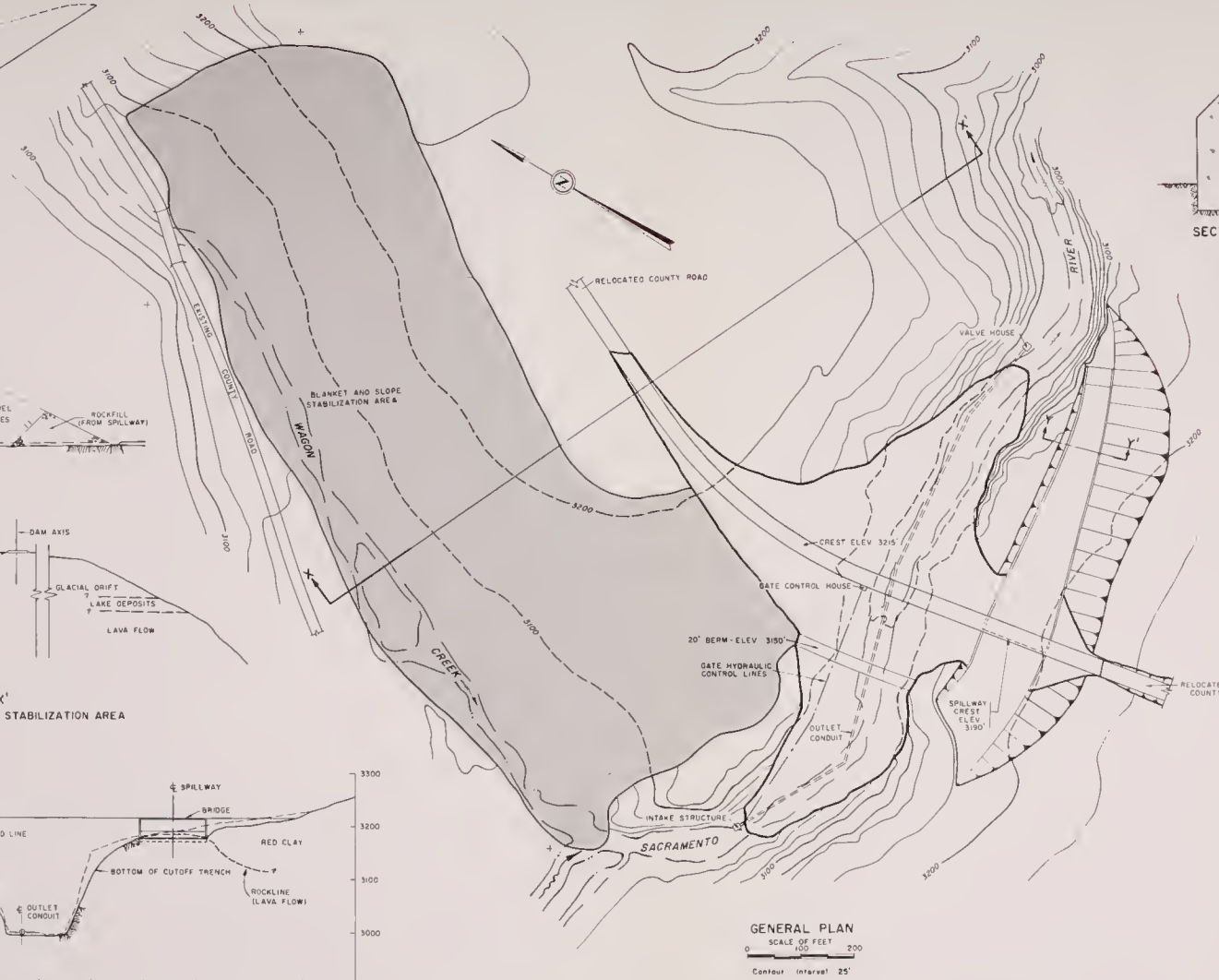
MAXIMUM SECTION THROUGH DAM



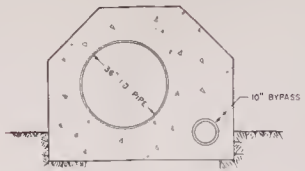
SECTION X-X'
SECTION THROUGH BLANKET AND SLOPE STABILIZATION AREA
NOT TO SCALE



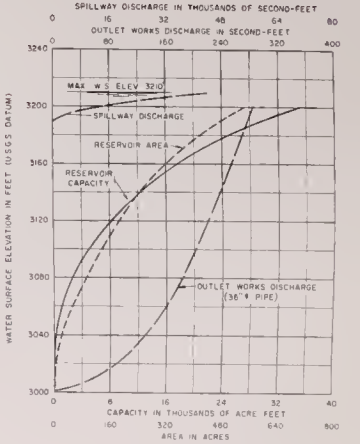
PROFILE OF DAM
LOOKING DOWNSTREAM



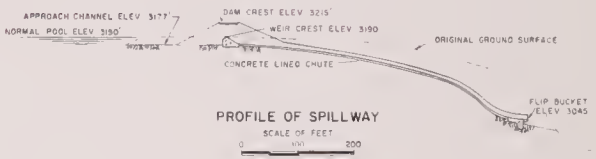
GENERAL PLAN
SCALE OF FEET
0 100 200
Contour Interval 25'



SECTION OUTLET CONDUIT
SCALE OF FEET
0 2 4



AREA-CAPACITY-DISCHARGE CURVES



PROFILE OF SPILLWAY
SCALE OF FEET

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
MT SHASTA CITY-DUNSMUIR AREA INVESTIGATION

BOX CANYON DAM
GENERAL PLAN AND SECTIONS
1962